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LEUCOGASTER AND LEUCOPHLEBS IN NORTH AMERICA

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LEUCOGASTER

Leucogaster Hesse, Jahrb. f. wiss. Bot. **13**: 189–194. 1882; Bot. Centralbl. **40**: 1–4, 33–36. 1889; Hypog. Deutschl. **1**: 68–71. 1891; Saccardo, Syll. Fung. **9**: 281. 1891, **14**: 249. 1899, **17**: 240. 1905; Fischer in Engler & Prantl, Nat. Pflanzenfam. I. **1****: 311. 1899; Hollós, Magyarország Földalatti Gombai, 97–99. 1911.—*Leucophleps* Harkness, Cal. Acad. Sci. Proc. Bot. III. **1**: 257–259. 1899 (in part).

The type species of the genus is *Leucogaster liosporus* Hesse.

Fructifications globose to irregular, hypogaeous to emergent, fleshy or waxy; fibrils sometimes present, leading to rhizomorphs; columella, stipe, and sterile base absent; peridium usually thin and fragile, sometimes rupturing at maturity; cavities frequently polyhedral, usually filled with spores embedded in a gelatinous mass; septa homogeneous, with or without a distinct trama, often gelatinizing at maturity; basidia from subglobose to ovoid and subcylindric, mostly 4-spored, sometimes 3- or 5-spored; spores hyaline or slightly colored, with various surface markings embedded in a gelatinous spherical mass.

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Leucogaster was placed by its author next to *Melanogaster* Corda, because the basidia are in less definitely organized layers than in the other genera of the *Hymenogastraceae*, while Fischer, considering its inseparable peridium and spore characters, placed it between *Hydnangium* Wallroth and *Rhizopogon* Fries. In several species the basidia are long-pedicellate, a fact which, in the absence of cystidia or paraphyses, often give them the appearance of being scattered throughout the cavity, especially where the razor tangles the long, thread-like pedicels. The basidium is usually little more than the slightly enlarged end of a hypha and frequently much smaller than one of the spores produced by it. In the development of the sporophore cavities seem to be formed in the outer sterile layer of the gleba when the hyphae cease to elongate and produce basidia at the ends of the hyphae, while the surrounding hyphae elongate rapidly, separating the basidia. A gel, which is either secreted or formed by the disintegration of many of the hyphae in the cavity, fills the cavity and oozes out as a milky liquid when the fructification is cut open. The peridium is thin and usually homogeneous with the gleba. It is variable in thickness, owing to the manner in which the new cavities are formed.

Fischer[1] has recently described development in *Leucogaster floccosus* Hesse. He finds the cavities not lined with a hymenium in the youngest stage studied (3.5 × 2.5 mm.) but filled with loose tissue of thin-walled hyphae which show marked but wholly irregular swelling and form a loose pseudoparenchyma. The trama consists of parallel, thin-walled, interwoven hyphae. In a later stage (11 × 4–5 mm. in diameter) the cavity has nearly disappeared in a formless gel and the basidia push out into it from the septa.

Fischer evidently studied *L. floccosus* Hesse, although he was not sure that it might not have been *L. fragrans* Mattirolo. A study of the type of the latter shows it to be quite distinct from *L. floccosus*, although it falls into synonymy elsewhere (see p. 403). In the Farlow Herbarium there is a collection of *L. floccosus* from Hesse, dated 1900, which agrees with the description very well.

[1] Fischer, E. Mykologische Beiträge, 25. Jugendstadien des Fruchtkörpers von Leucogaster. Naturf. Ges. Bern, Mitt. **1921**: 301–307. (20–26). 1922.

It contains 3 large and 2 small fructifications, one of the latter 2 × 3 mm. in diameter, the other 4 × 5 mm. They have been preserved in alcohol since 1900 and probably are somewhat shrunken. When collected they were probably about the age of those examined by Fischer. In the smaller specimen the cavities are filled with cells, somewhat irregular on account of mutual pressure, which expand to a spherical form when treated with a dilute solution of potassium hydroxide. A further study shows them to be spores (?) borne acrogenously on short branches of curved or zig-zag hyphae, or sometimes terminally on large hyphae springing from the trama (see pl. 11, fig. 10). When closely packed together they appear in rows, reminding one of the appearance of aecidiospores of the *Uredinales*. As the only material available was no longer viable, whether these organs are true spores must remain in doubt for the present.

Secondary spore forms have not been reported very frequently in *Gasteromycetes*. Fischer[1] has reported cells which he called gemmae in *Sphaerobolus*, and Eidam[2] and Brefeld[3] found that oidia are produced in poorly nourished cultures of the *Nidulariaceae*. In the *Hymenomycetes* most of the literature has been carefully reviewed by Lyman,[4] Zeller[5] and Snell,[6] who show that other spore forms are much more common in these fungi. We[7] have already noted conidia-like cells produced at the surface of *Arcangeliella caudata* Z & D., although we did not attempt to germinate them. The spores of the present fungus resemble the basidio-

[1] Fischer, E. Zur Entwickelungsgeschichte der Gasteromyceten. Bot. Zeit. **42**: 433–443, 449–462, 465–475, 485, 494. *pl. 7*. 1884.

[2] Eidam, E. Die Keimung der Sporen und die Entstehung der Fruchtkörper bei den Nidularieen. Beitr. z. Biol. d. Pflanzen **2**: 221–249. *pl. 10*. 1876.

[3] Brefeld, O. Botanische Untersuchungen über Schimmelpilze **3**: 1–226. *pl. 1–11*. 1877.

[4] Lyman, G. R. Culture studies on polymorphism of Hymenomycetes. Boston Soc. Nat. Hist., Proc. **33**: 125–209. *pl. 18–26*. 1907.

[5] Zeller, S. M. Studies in the physiology of the fungi. II. Lenzites saepiaria Fries, with special reference to enzyme activity. Ann. Mo. Bot. Gard. **3**: 439–512. (See pp. 443–444). *pl. 8–9*. 1916.

[6] Snell, W. H. Studies of certain fungi of economic importance in the decay of building timbers with special reference to the factors which favor their development and dissemination. U. S. Dept. Agr. Bull. 1053: 1–47. *pl. 1–8*. 1922.

[7] Zeller, S. M., and Dodge, C. W. Arcangeliella, Gymnomyces, and Macowanites in North America. Ann. Mo. Bot. Gard. **6**: 49–59. 1919.

spores so closely on account of the thick gelatinous sheath that they may be mistaken for the latter. In *Leucophlebs candida* Harkness, one finds that the spore frequently has slipped out of its sheath, reminding one of the germination of the chlamydospores of *Fistulina*, reported by de Seynes.[1]

In 1899 Harkness described a new genus, *Leucophlebs*, based on 5 species, 3 of which are undoubtedly *Leucogaster* sp. The types of the 2 remaining species are in such a collapsed condition that it is difficult to interpret the structure, but apparently they are the imperfect condition of *Leucogaster*. For the present we would leave this genus among the *Fungi Imperfecti*, analogous to *Ceriomyces* Corda[2] (*Ptychogaster* Corda), a chlamydosporic stage of *Polyporus* Micheli ex Fries, in so far as the species have been connected with any perfect stage.

The relationships of *Leucogaster* and *Scleroderma* in connection with the forms originally described as *Phlyctospora* offer an opportunity for further investigation by those having access to young material. There seems to be a series of forms from such species as *Leucogaster luteomaculatus* and *L. floccosus* with their duplex peridia, through such forms as *L. citrinus* to *L. badius*, thence to *Scleroderma* (*Phlyctospora*) *fuscum* and *S.* (*Euscleroderma ?*) *dictyosporum* and *S.* (*Euscleroderma*) *aurantium*, in which there is a gradual thickening of the peridium, a thickening of the gelatinous envelope of the spore with a simultaneous increase in the depth of the warts and reticulations, which finds its most complete expression in the subgenus *Phlyctospora* of *Scleroderma*, and a sudden disappearance of the gelatinous sheath in the subgenus *Euscleroderma*. Observations on the development of *Scleroderma hypogaeum* Zeller by one of us show that the spores of this species are at first surrounded by a thick gelatinous sheath which, upon maturity and drying, disappears. Further, it will be noted that in the above series of forms, all stages are represented, connecting forms with a well-defined and definitely organized hymenium with those in which the basidia are scattered throughout the

[1] de Seynes, J. Recherches pour servir à l'histoire naturelle des végétaux inférieurs. I. Des Fistulines. v+71 pp. 7 *pl.* Paris, 1874.

[2] Not Battara. *Ceriomyces* Battara has been used as a segregate of *Boletus* Fries (see North American Flora 9: 136. 1910).

tissue. The series also illustrates a progression from forms which gelatinize throughout to those which finally become dry and dusty at maturity. Until a morphological study can be made, it seems wise to consider all forms with light-colored and hyaline spores enclosed in a definite, globose, gelatinous sheath as species of *Leucogaster*, reserving the dark-colored spore groups for the subgenus *Phlyctospora* of *Scleroderma*.

As in our previous work, we have used as a standard for color descriptions Ridgway, 'Color Standards and Color Nomenclature,' Washington, D. C., 1912. In citing specimens we have given the data accompanying the specimens. Wherever possible the location of the specimens has also been given.

In conclusion we gratefully acknowledge our indebtedness to all who have aided us in this work. We are indebted to the Missouri Botanical Garden for the use of the library and herbarium; to Dr. L. R. Abrams for access to the Dudley Herbarium at Leland Stanford Jr. University, and to Prof. J. McMurphy for assistance in the study of Harkness' specimens there; to Dr. E. A. Burt for access to his private herbarium and for helpful suggestions; to the late W. G. Farlow for access to the collections from Hesse in the Cryptogamic Herbarium of Harvard University, and, since Dr. Farlow's death, to Dr. R. Thaxter for helpful suggestions and for access to his own collections as well as those of the Farlow Herbarium; to Dr. H. D. House for the privilege of studying the type of *Hymenogaster anomalus* Peck from the New York State Museum; to Mr. C. G. Lloyd for access to specimens in the Lloyd Museum; to Mr. H. E. Parks for assistance in collecting fresh material; and to Dr. W. A. Setchell and to Dr. N. L. Gardner for access to the University of California Herbarium.

Key to the Species of Leucogaster and Leucophlebs

1. Peridium duplex, thin, 60–80 μ thick, white spotted with yellow, becoming reddish on drying, basidia linear-oblong..... *Leucogaster luteomaculatus* (p. 394)
1. Peridium simplex, although sometimes with flocculent patches, then much thicker..... 2
2. Spores over 16 μ in diameter..... *L. nudus* (p. 404)
2. Spores under 16 μ in diameter..... 3
3. Peridium of large hyphae (more than 4 μ in diameter)..... 4
3. Peridium of slender hyphae..... 6

4. Septa of long hyphae, peridium very thick.....*L. liosporus* (p. 402)
4. Septa of pseudoparenchyma, peridium 140–220 μ thick..... 5
5. Spores reticulate.....*L. Tozziana* (p. 403)
5. Spores aculeate.....*L. Bucholtzii* (p. 404)
6. Peridium thin (under 180 μ thick)..... 7
6. Peridium thick (over 200 μ thick)..... 12
7. Septa thick, 100–150 μ thick, gleba becoming bay or darker.*L. floccosus* (p. 402)
7. Septa medium, 75–100 μ thick, gleba white..... 8
7. Septa thin, 20–50 μ thick..... 9
8. Cavities empty, subhymenial layer compact.....*L. odoratus* (p. 396)
8. Cavities filled, subhymenial layer loosely woven..*L. foveolatus* (p. 397)
9. Peridium 15–20 μ thick, surface studded with shallow depressions, white .....*Leucophlebs candida* (p. 407)
9. Peridium 120–180 μ thick..... 10
9. Peridium 15–60 μ thick, pseudoparenchymatous, red..... .....*Leucogaster rubescens* (p. 395)
10. Peridium containing pigmented bodies, citron-yellow..*L. citrinus* (p. 398)
10. Peridium uniform..... 11
11. Septa of 3 indefinite layers, basidia long-pedicelled, paraphyses none, giving the hymenium an arachnoid appearance, sterigmata short .....*L. araneosus* (p. 399)
11. Septa thinner, homogeneous, spores 13 μ in diameter, "sterigmata "long .....*Leucophlebs magnata* (p. 406)
12. Septa thin, 60–120 μ thick, basidia clavate, 22×8 μ, spores 11–13 μ in diameter, sterigmata short.....*Leucogaster anomalus* (p. 399)
12. Septa thick, 150–200 μ thick, basidia pyriform..... 13
13. Basidia 20–24×12 μ, spores 12–16 μ in diameter, sterigmata short..... .....*L. badius* (p. 400)
13. Basidia 7–8×5–6 μ, pedicellate, spores 8–10 μ in diameter, sterigmata long .....*L. fulvimaculosus* (p. 401)

1. Leucogaster luteomaculatus Zeller & Dodge, sp. nov.

Fructificationes globosae, 2.5 × 1 cm. metientes, siccatae 1.5 × 0.8 cm., recentes calceae, cum maculis sordide luteis (Thaxteri memoranda), siccatae "ox-blood red" vel "garnet-brown" (Ridgway), superficie inaequali, nitenti; funiculi anastomosantes, hinc indeque liberi, nigri, nitentes; peridium 60–80 μ crassitudine, duplex, strato extero facile ab intero separante pannis relictis, 20–30 μ crassitudine, hyphis crassis, septatis, olivaceis-brunneis sub lente, contexto, strato intero 40–50 μ crassitudine, hyphis tenuibus, badiis, granulatis, dense contexto; gleba lactea recens (Thaxtero teste), siccata "cinnamon" vel "clay-color" (Ridgway); locelli globosi vel angulosi, impleti; septa tenua, 50–60 μ crassitudine, hyalina, hyphis parallelis, crassis, tenuibus cum parietibus, hyalinis contexta, scissilia; basidia hyalina, 7 × 12 μ, anguste oblonga, bispora; sterigmata 2–4 μ longitudine; sporae dilute olivaceae sub lente, globosae, minute verrucosae in vaginis gelatinosis inclusae, 7–9 μ.

Habitat sub foliis in fagetis, Carolina boreali. Aestate.

Type: in Thaxter Herb.

Fructifications globose, 2.5 × 1 cm., drying 1.5 × 0.8 cm., chalk-white with yellow flecks (Thaxter's field notes), becoming

ox-blood red to garnet-brown on drying, surface uneven, shining; fibrils anastomosing, free in places, black, shining; peridium 60–80 μ thick, duplex, outer layer readily separating from the inner, leaving patches 20–30 μ thick, of large, septate, olive-brown hyphae; inner layer 40–50 μ thick, of slender, reddish brown, granular, closely woven hyphae; gleba milk-white when fresh, drying cinnamon or clay-color; cavities globose to polyhedral, filled; septa thin, 50–60 μ, hyaline, of large, parallel, thin-walled, hyaline hyphae, scissile; basidia hyaline, 7 × 12 μ, narrowly oblong, 2-spored; sterigmata 2–4 μ long; spores light olivaceous under the microscope, globose, minutely verrucose with a gelatinous sheath, 7–9 μ in diameter.

Under leaf mould in beech forests. Europe and North America. Summer.

The duplex character of the peridium, the color both when fresh and upon drying, as well as the very thin peridium, should serve to distinguish this species from other members of the genus.

Specimens examined:

Exsiccati: D. Saccardo, Mycoth. Ital., 1424.

Switzerland: *E. Butignot* (in Lloyd Mus. 025).

Italy: Firenze, Vallombrosa, *A. Fiori* in D. Saccardo, Mycoth. Ital., 1424 (in Farlow Herb. at Harvard Univ.).

North Carolina: Cranberry, *R. Thaxter, 3*, type (in Thaxter Herb. and in Farlow Herb. at Harvard Univ.).

California: Santa Clara County, *H. E. Parks, 908* (immature) and *915* (in Univ. Cal. Herb., and in Dodge Herb. 2104).

2. Leucogaster rubescens Zeller & Dodge, sp. nov.

Fructificationes subglobosae vel irregulares, primum albidae vel carneae, deinde "brick-red" vel "Hessian brown" (Ridgway), superficie levi vel inaequali, viscida; funiculi concolores saturatioresve, innati-appressi; peridium 15–35 μ crassitudine (aliquando 40–60 μ) pseudoparenchymate gelatinoso, fragile, "orange rufous" (Ridgway) siccatum; gleba siccata cremea vel "ivory-yellow" (Ridgway) secata; locelli circa 0.5 mm., globosi vel angulosi; septa hyalina, 35–55 μ crassitudine, hyphis tenuibus scissilescentibus; basidia hyalina, pyriformia, 15–25 × 8–14 μ, pedicello 50–125 μ longitudine, tetraspora, sterigmatibus 2–4 μ longitudine; sporae sphaericae oblongaeve, echino-reticulatae, subhyalinae, 11–15 μ (cum vagina gelatinosa, 6–10 μ sine vagina).

Sub foliis in aceretis. Oregon. Veri.

Type: in Zeller Herb., Dodge Herb., and Oregon Agr. Coll. Herb.

Fructifications subglobose to irregular, at first whitish to flesh-pink, becoming brick-red to Hessian brown, surface smooth, uneven, viscid when moist; fibrils concolorous or darker, innate-appressed; peridium usually 15–35 μ thick (sometimes 40–60 μ), composed of gelatinized pseudoparenchyma, drying brittle and orange rufous, lined with the fine, hyaline hyphae of the outer layer of the gleba (showing white in cross-section); gleba drying cream-color or ivory-yellow when cut after drying; cavities averaging about 2 to the mm., globose to polyhedral, lined with a clear gelatinous mucus, embedding the long-pedicelled basidia and spores; septa hyaline, 35–55 μ thick, of thin-walled hyphae, becoming scissile; basidia not in a definite hymenium, hyaline, pyriform, 15–25 × 8–14 μ, on pedicels 50–125 μ long, 4-spored; sterigmata 2–4 μ long; spores spherical to oblong, echino-reticulate, almost hyaline, 11–15 μ (including gelatinous sheath), spore alone 6–10 μ.

In leaf mould under maples. Oregon. May.

The thin pseudoparenchymatous peridium, which is vivid red, and the echino-reticulate spores separate this species from others of the genus.

Specimens examined:

Oregon: Corvallis, *L. M. Boozer*, type (in Oregon Agr. Coll. Herb. 3706, in Zeller Herb. 2322, and in Dodge Herb. 2072).

3. Leucogaster odoratus (Harkness) Zeller & Dodge, comb. nov.

Leucophleps odorata Harkness, Cal. Acad. Sci. Proc. Bot. III. **1**: 258. 1899; Saccardo & Sydow in Sacc. Syll. Fung. **16**: 252. 1902.

Illustrations: Harkness, Cal. Acad. Sci. Proc. Bot. III. **1**: *pl. 43. f. 9;* Rev. Myc. **22**: *pl. 204. f. 12.*

Type: in Dudley Herb. at Leland Stanford Jr. Univ.

Fructifications oblong or irregularly lobed, large, 3–4 cm. in diameter, light orange, fading in alcohol; fibrils and columella wanting; peridium thin, about 100 μ thick, of compactly woven, gelatinized hyphae, homogeneous with the septa; gleba white, cavities round, empty; septa about 75 μ thick, of 3 layers, the middle layer of parallel, gelatinized hyphae, subhymenial layers of closely interwoven hyphae, hymenium of long-pedicelled

basidia, 20 × 5 μ; no paraphyses; sterigmata short; spores hyaline, reticulate in gelatinous sheath, globose to slightly ellipsoidal, 8–11 μ in diameter.

California. June to July.

The freshly cut gleba exudes a milky juice, probably a dense suspension of spores, as no definite latex organs were seen. This, with the large, spherical empty cavities and its color, makes it quite easy to recognize in the field.

Specimens examined:

California: Shasta County, Castle Crag, *H. W. Harkness, 251*, type (in Dudley Herb. at Leland Stanford Jr. Univ.); Santa Clara County, Saratoga, Boys' Outing Farm, *H. E. Parks & C. W. Dodge* (in Dodge Herb. 1529).

4. Leucogaster foveolatus (Harkness) Zeller & Dodge, comb. nov.

Leucophleps foveolata Harkness, Cal. Acad. Sci. Proc. Bot. III. 1: 258. 1899; Saccardo & Sydow in Sacc. Syll. Fung. **16**: 252. 1902.

Type: in Dudley Herb. at Leland Stanford Jr. Univ.

Fructifications subglobose, 1 cm. in diameter, white or faintly citron color; fibrils few, small, white; columella wanting; peridium thin, 75–100 μ thick, of very slender, compactly woven hyphae, homogeneous with the septa which show through as reticulations or pits on the surface; gleba white, cavities rounded, filled with hyphae; septa 75–100 μ thick, of 3 layers, the middle layer of compactly woven, gelatinized hyphae, subhymenial layer of larger, more loosely woven hyphae; basidia clavate, 12 × 7 μ, disappearing, leaving spores sticking to walls of the cavity hyphae; sterigmata long; spores hyaline, guttulate, reticulate in a gelatinous sheath, sometimes slipping out at maturity, globose to slightly ellipsoidal, 7–12 μ.

Moist earth. British Columbia to California. July to September.

Leucophlebs gibbosum Harkness, herb. nom., is a lighter form, irregular in shape but structurally similar (Harkness 124, without locality data in Dudley Herb. at Leland Stanford Jr. Univ.).

Specimens examined:

British Columbia: south of Beavermouth along Quartz Creek Trail, *C. W. Dodge, 1545* (in Dodge Herb.).

California: Marin County, Mill Valley, *H. W. Harkness, 209*, type (in Dudley Herb. at Leland Stanford Jr. Univ.).

5. Leucogaster citrinus (Harkness) Zeller & Dodge, comb. nov

Leucophleps citrina Harkness, Cal. Acad. Sci. Proc. Bot. III **1**: 259. 1899; Saccardo & Sydow in Sacc. Syll. Fung. **16**: 252. 1902.

Illustrations: Harkness, Cal. Acad. Sci. Proc. Bot. III. **1**: *pl. 43, f. 8;* Rev. Myc. **22**: *pl. 204, f. 10–11.*

Type: in Dudley Herb. at Leland Stanford Jr. Univ.

Fructifications solitary, subglobose, 2 cm. in diameter, "citron color, imparting a reddish color to alcohol when immersed" (Harkness), becoming dirty vinaceous buff when dry; peridium 140–170 μ thick, composed of uniform, small, closely woven hyphae, appearing light chalcedony-yellow, homogeneous except for included sand and globose to irregular pigmented bodies, 12–20 μ in diameter, appearing granular, tawny to buckthorn-brown; gleba ivory-yellow when dry; cavities large, globose, empty; septa 20–30 μ thick between hymenial layers, composed of very slender, closely woven, hyaline hyphae; basidia narrowly clavate, 16–25 × 2–4 μ, hyaline, filled with oil globules, 2–4-spored; sterigmata 5–7 μ long, slender; spores brown in mass, sybhyaline under the microscope, pitted or minutely verrucose, 7–11 μ in diameter, surrounded by a gelatinous sheath approximately 1–2 μ thick.

Under manzanita and laurel. California. April.

Cremogaster levisporus Mattirolo agrees with this species in all respects except that it is slightly younger material and the spore is scarcely pitted yet.

Specimens examined:

California: Marin County, Mt. Tamalpais, *H. W. Harkness, 168*, type (in Dudley Herb. at Leland Stanford Jr. Univ. and in Farlow Herb. at Harvard Univ.); Santa Clara County, Saratoga, Boys' Outing Farm, *Dale Parks* (in Univ. Cal. Herb., under H. E. Parks, 816); Call of the Wild, *H. E. Parks, 37b* (in Univ. Cal. Herb.); San Antonio Mts., *I. M. Johnston*, type of *Cremogaster levisporus* Mattirolo (in Lloyd Mus.).

6. Leucogaster araneosus Zeller & Dodge, sp. nov.

Fructificationes globosae, 0.6 cm. in diametro metientes, servatae "snuff-brown" vel "bister" (Ridgway); funiculi magni sed non prominentes, pauci, semi-innati, subramosi; peridium 130–180 μ crassitudine, simplex, hyphis dilute brunneis tenuissimis dense contextum; gleba alba, fulvis cum maculis; locelli subglobosi, impleti; septa tenua, 40–50 μ crassitudine inter hymenia, compacta, stratis tribus composita, strato medio dilute brunneo, stratis caeteris hyalinis; stratum hymeniale quasi araneosum (unde nomen); paraphyses nulli; basidia hyalina, granulato-guttulata, 8–10 × 6–8 μ, piriformia, in pedicellis ad 300 μ longitudine imposita, tetraspora; sporae hyalinae, globosae, alveolato-reticulatae, angulis alveolarum prominentibus velut spinis obtusis, in vaginis gelatinosis inclusae, 8–11 μ in diametro.

Habitat in Carolina boreali. Aestate.

Type: in Thaxter Herb.

Fructifications globose, 0.6 cm. in diameter in preserved material, snuff-brown to bister; fibrils large but not prominent, few, half-immersed, somewhat branched; peridium 130–180 μ thick, simplex, of closely woven, very slender, light brown hyphae; gleba white with tawny spots; cavities subglobose, filled; septa thin, 40–50 μ thick between hymenia, compact, of 3 layers, the middle layer being light brown, the other 2 layers hyaline; hymenial layer arachnoid; paraphyses none; basidia hyaline, granulate-guttulate, 8–10 × 6–8 μ, pyriform, on pedicels up to 300 μ long, 4-spored; spores hyaline, globose, alveolate-reticulate, angles of alveoli projecting as blunt spines, in a gelatinous sheath, 8–11 μ in diameter.

North Carolina. Summer.

Specimens examined:

North Carolina: Cranberry, *R. Thaxter, 96* (in Thaxter Herb. and Farlow Herb. at Harvard Univ.).

7. Leucogaster anomalus (Peck) Zeller & Dodge, comb. nov.

Hymenogaster anomalus Peck, N. Y. State Mus. Bull. 116: 31–32. 1907 (also cited as N. Y. State Ed. Dept. Bull. 404: 31–32. 1907, and as Rept. State Botanist [N. Y.] **1906**: 31–32. 1907); Saccardo & Trotter in Sacc. Syll. Fung. **21**: 496. 1912.

Type: in Coll. N. Y. State and in U. S. Nat. Herb.

Fructifications globose to irregular, 1–2.5 cm. in diameter, cinnamon-buff, clay-color, and tawny olive to Mikado brown above, Hay's russet and liver-brown below, "glabrous, slightly lacunose, often with a root-like strand of mycelium at the base,

. . . sterile base obsolete or nearly so, odor slight, not disagreeable," (Peck); peridium 240–520 μ thick, grenadine to English red near the surface to hyaline within, composed of very slender interwoven hyphae; gleba amber-brown to Sudan brown, sometimes lighter; cavities large, mostly more than 1 mm. in diameter, subglobose to irregular, empty; septa 60–120 μ, composed of very closely woven, hyaline hyphae, not scissile; cystidia none, paraphyses clavate, granularly guttulate; basidia clavate, 22–24 × 8 μ, hyaline, 4-spored; spores almost sessile, dilute cream-colored to hyaline, globose, 11–13 μ in diameter, uninucleate, surface pitted, giving the appearance of hexagonal reticulations, surrounded by a hyaline, gelatinous sheath.

Hypogaeous, in woods. District of Columbia. August to September.

Specimens examined:

District of Columbia: Washington, Rock Creek Park, *T. E. Wilcox*, type (in Coll. N. Y. State and U. S. Nat. Herb.).

8. Leucogaster badius Mattirolo, R. Accad. Sci. Torino, Mem. II. **53**: 356. 1903; Saccardo & Saccardo in Sacc. Syll. Fung. **17**: 240. 1905.

Illustrations: Mattirolo, R. Accad. Sci. Torino, Mem. II. **53**: *pl. unnumbered, f. 1–3.*

Type: probably in Mattirolo Herb. and in Collezione Beccari, Herb. Cesatiano at the R. Ist. Bot. di Roma, but not seen.

Fructifications subglobose, 1 cm. in diameter, raw sienna to raw umber, surface pitted, glabrous; stipe very slender, from a very slight, inconspicuous, sterile base; peridium 200–340 μ thick, ochraceous-buff, stupose, composed of very slender hyphae; gleba raw umber; cavities polygonal, filled with spores in a gelatinous mass due to deliquescence, 0.7–1.0 mm. in diameter; septa 160–200 μ thick, composed of compactly woven, gelatinous, cream-colored hyphae; cystidia none; basidia hyaline, pyriform, 20–24 × 12 μ, 4-spored, guttulate; spores almost sessile, subglobose, 12–16 μ in diameter, cream-colored, surface pitted, giving the appearance of hexagonal reticulations, surrounded by a hyaline, gelatinous sheath.

On the ground, under leaves. Italy and New York, July and August.

Specimens examined:
New York: East Galway, *E. A. Burt* (in Burt Herb.).

9. Leucogaster fulvimaculosus Zeller & Dodge, sp. nov.

Fructificationes globosae, 2.0–2.5 cm. in diametro metientes, siccatae "cinnamon buff," "tawny" (Ridgway) maculatae; funiculi non prominentes, pauci, concolori; peridium 375–425 μ crassitudine, simplex, compactum, hyphis tenuibus dense contextum; gleba "warm buff" (Ridgway) vel dilutior; locelli globosi vel angulosi, semi-impleti; septa 150–180 μ crassitudine, hyalina, hyphis tenuibus dense contexta, non scissilia; basidia hyalina, 7–8 × 5–6 μ, piriformia, in pedicellis 90 μ longitudine imposita, trispora; sterigmata conica, 2 μ longitudine; sporae hyalinae servatae, brunneae siccatae, sphericae vel ovoideae, verrucosae vel reticulatae, in vaginis gelatinosis inclusae, 8–10 μ diametro.

Habitat in silvis udosis. Civ. Noveboracensi. Aestate.

Fructifications globose, 2.0–2.5 cm. in diameter, drying cinnamon-buff, spotted with tawny; fibrils not prominent, few, concolorous; peridium 375–425 μ thick, simplex, compact, of closely woven, slender hyphae; gleba warm buff or lighter; cavities globose or polyhedral, half filled; septa 150–180 μ thick, hyaline, of closely woven slender hyphae, not scissile; basidia hyaline, 7–8 × 5–6 μ, pyriform, on pedicels about 90 μ long, 3-spored; sterigmata conical, 2 μ long; spores hyaline in preserved material, brown in dry material, spherical to ovoid, verrucose to reticulate, leaving a pore where detached from the sterigma, inclosed in a gelatinous sheath, 8–10 μ in diameter.

Damp woods. New York. Summer.

The peridium of this species appears to be variable in thickness, new cavities seeming to form in the inner layer as the fructification increases in size, with the hyphae next the basidia-bearing hyphae gelatinizing and finally disappearing. A study of young material is very desirable for further interpreting this phenomenon.

Specimens examined:
New York: Long Island, Cold Spring Harbor, *A. F. Blakeslee*, type (in Farlow Herb. at Harvard Univ.).

EXTRA-LIMITAL SPECIES

The following species of *Leucogaster* have not yet been noted from North America, but are included in order to assist in referring material to them in case they should be found later, as individual species in this family have wide ranges.

1. Leucogaster liosporus Hesse, Jahrb. f. wiss. Bot. **13**: 190. 1882; Hypog. Deutschl. **1**: 70–71. 1891; Saccardo, Syll. Fung. **9**: 281. 1891.—*Octaviania silesiaca* Becker, Die Natur **35**: 356. 1886, fide Schroeter in Cohn, Kryptog.-Fl. von Schlesien 3^1: 710–711. 1889.—*Octaviania* ? *Gautieria* ? *pityophila* Becker, Die Natur **35**: 356. 1886, fide Schroeter in Cohn, Kryptog.-Fl. von Schlesien 3^1: 710–711. 1889.

Illustrations: Hesse, Jahrb. f. wiss. Bot. **13**: *f. 1–6;* Hypog. Deutschl. **1**: *pl. 3. f. 14–15.*

Type: location unknown to us.

Fructifications very irregular, variable in size, citron-yellow, odor none; fibrils free, branched, becoming 3 mm. thick at maturity; peridium thick, 1.5–2.5 mm. thick when fresh (teste Hesse), 100–140 μ when preserved in alcohol, smooth, composed of thick yellowish hyphae; gleba white; cavities polygonal, larger at the center than at the peridium, filled at maturity; septa composed of long, thin hyphae; basidia broadly clavate to subglobose; sterigmata very short; spores 12 μ in diameter, rough, surrounded by a gelatinous sheath.

In birch woods. Central Europe.

A specimen in the von Hoehnel Herbarium, 2605a, agrees with the description of this species, except that the cavities are elongated radially from the base, as Hesse has figured in one case for *L. floccosus*, and are not filled at maturity. The *Leucophlebs* stage of this specimen shows spores borne terminally on short branches of the cavity hyphae. These spores resemble basidiospores but have smoother and thinner walls and small germ pores. The sporiferous branch of a cavity hypha usually remains attached to the spore.

Specimens examined:

Austria: Reinberg bei Altenmarkt, Coronnathal, *Fr. von Hoehnel, 2605a* (in von Hoehnel Herb. at Farlow Herb., Harvard Univ.).

2. Leucogaster floccosus Hesse, Bot. Centralbl. **40**: 1–4, 33–36. 1889; Hypog. Deutschl. **1**: 68–70. 1891; Saccardo, Syll. Fung. **9**: 281. 1891.

Illustrations: Hesse, Bot. Centralbl. **40**: *pl. 1, 2. f. 1–9;* Hypog.

Deutschl. **1**: *pl. 3, f. 8–13; pl. 5, f. 8; pl. 7, f. 1–3; pl. 8, f. 1–20; pl. 9, f. 1–13.*

Type: location unknown to us.

Fructifications irregular, variable in size, light yellow (Hesse), bay to auburn in alcohol; fibrils loose, round, black or nearly so; peridium with thick, flocculent concolorous patches, 120–150 μ thick, composed of small hyphae, outer ones colored to a depth of 10 μ, inner ones gelatinizing; gleba slightly darker, waxy in preserved specimens; septa hyaline, 100–150 μ, composed of large, closely woven hyphae; basidia 2–3-spored, 7 × 12 μ; spores echinulate, 4 μ in diameter, surrounded with a gelatinous sheath, making a total diameter of 7–10 μ.

Hypogaeous in birch and oak woods, England and Germany. August and September.

Specimens examined:

Exsiccati: Rabenhorst, Fung. Eur. 38.

England: Batheaston, *C. E. Broome* (in Rabenhorst, Fung. Eur., 38, under the name *Hymenogaster citrinus* Vitt., copy in Farlow Herb. at Harvard Univ.).

Germany: Hesse-Nassau, Kirchain, *R. Hesse, 1902* (in Farlow Herb. at Harvard Univ.).

3. Leucogaster Tozziana (Cavara & Saccardo) Mattirolo in litt., comb. nov.

Endogone Tozziana Cavara & Saccardo, Nuov. Giorn. Bot. Ital. II. **7**: 296. Jy. 1900; Saccardo & Sydow in Sacc. Syll. Fung. **16**: 816–817. 1902.—*Leucogaster* sp. Baccarini, Nuov. Giorn. Bot. Ital. II. **10**: 80. 1903; Thaxter, Am. Acad. Arts & Sci., Proc. **57**: 326. 1922.—*Leucogaster fragrans* Mattirolo, Malpighia **14**: 267. Dec. 1900; Saccardo & Sydow in Sacc. Syll. Fung. **16**: 249. 1902.

Type: in Cavara Herb. and portion in Mattirolo Herb.

Fructifications irregular or gibbous, sulcate, 1–2.5 cm. in diameter, sulphur-colored, becoming vinaceous buff or darker in alcohol; odor of *Tuber Borchii* (Mattirolo); fibrils adherent to almost free, concolorous, sometimes surrounding the fructification, sometimes mostly on the under side; peridium 140–220 μ thick, simplex, composed of large, parallel, thin-walled hyphae, 4–7 μ

in diameter, forming a pseudoparenchyma; gleba white, becoming Sayal brown in alcohol, cavities variable in size, polygonal; septa 40–60 μ thick, composed of pseudoparenchyma much as in the peridium; basidia clavate, 20 × 7 μ, disappearing early; sterigmata 2 μ long; spores globose, 12 μ in diameter, reticulate, surrounded by a gelatinous sheath.

In pine and fir forests. Italy.

Specimens examined:

Italy: Vallombrosa, *O. Mattirolo*, Nov. 23, 1899, cotype of *Leucogaster fragrans* (in Mattirolo Herb. and portion in Thaxter Herb.); *O. Mattirolo*, 1910 and undated specimen (in Lloyd Mus. unnumbered and 064); Nocciuolo sopra Vallombrosa, *F. Cavara*, type (preparation from Mattirolo in Thaxter Herb.).

4. Leucogaster Bucholtzii Mattirolo, Malpighia **14**: 267–268. 1900; Saccardo & Sydow in Sacc. Syll. Fung. **16**: 249. 1902.

Type: location unknown to us.

Characters of *L. Tozziana* (Cav. & Sacc.) Matt. with aculeate, instead of reticulate, spores.

In fir forests. Vallombrosa, Italy. Summer.

There seems to be so little in the original description to separate this species from *L. Tozziana* that we are inclined to regard it as a variety of this species, but reserve our decision until authentic material has been studied. It is possible that a careful comparison of collections referable here would show all the variations between fructifications with reticulate spores and those with aculeate ones.

5. Leucogaster nudus (Hazslinszky) Hollós, Mus. Nat. Hungarici, Ann. **6**: 319. 1908; Magyarország Földalatti Gombai 98, 208. 1911 (excl. syn.).—*Hydnangium nudum* Hazslinszky, K. K. Zool.-bot. Ges. in Wien, Verhandl. **25**: 64–65. 1875; Magyar Tudományos Akad. Termeszettud. Közl. **13**: (9). 1875 (often cited as Magyarhon hasgombai, 9. 1876); Hedwigia **16**: 44. 1877; Saccardo, Syll. Fung. **11**: 172. 1895.

Illustrations: Hazslinszky, K. K. Zool.-bot. Ges. in Wien, Verhandl. **25**: *pl. 3;* Hollós, Magyarország Földalatti Gombai *pl. 3, f. 34, 35, pl. 5, f. 33.*

Type: in Magyar Nemzeti Museum in Budapest (fide A. de Degen in litt.) not seen.

Fructifications globose to irregular by the coalescence of several fructifications, smooth with surface foveolate, 1–5 cm. in diameter, yellowish white, becoming fuscous; peridium thin, at first white and glistening, then ochroleucous, gelatinous to waxy; cavities subglobose to polyhedral, larger in the center of the fructification, filled at first, becoming empty; basidia pyriform, 4-spored, not in a distinct layer; spores sessile, spherical, ochraceous, blunt echinulate with thick yellow reticulations, gelatinous sheath smooth, 16–18 μ in diameter.

Under *Picea*, Bartfeld, Czechoslovakia. August.

From a study of Hazslinszky's material, Hollós thought *L. liosporus* was a synonym of this species. He did not see any of Hesse's material of *L. liosporus*, and we prefer to recognize both names until we have seen authentic material of both. The above description is a condensation of a translation from Hollós and should be used with caution, as Hollós seems to have conflated a description based on Hazslinszky's material with Hesse's description of *L. liosporus*. From the above description the present species seems more closely related to *Leucophlebs candida* Harkn.

LEUCOPHLEBS[1]

Leucophleps Harkness, Cal. Acad. Sci. Proc. Bot. III. **1**: 257–259. 1899; Fischer in Engler & Prantl, Die Nat. Pflanzenfam. I. **1****: 557. 1900; Saccardo & Sydow in Sacc. Syll. Fung. **16**: 251–252. 1902.—*Leucophlebs* Roumeguère, Rev. Myc. **22**: 83. 1900.

The type species of the genus is considered to be *Leucophlebs magnata* Harkness. Harkness did not definitely designate the type species but he probably had in mind *L. magnata*, for that species is followed by "gen. nov. et sp. nov.," while the other species which he included in the genus are followed by "sp. nov." only. The international rules do not cover this case, but canons 14 and 15 of the "American" code[2] and article 7g of the recom-

[1] Spelling corrected by Roumeguère, Rev. Myc. **22**: 83. 1900, in accordance with international rules.

[2] Nomenclature Commission of the Botanical Club of the American Association for the Advancement of Science. American code of botanical nomenclature. Torr. Bot. Club Bull. **34**: 167–178. 1907 (see p. 172–173).

mendations of the Committee on Nomenclature of the Botanical Society of America[1] both point to the adoption of this species as the type of this genus.

Fructifications globose to irregular, hypogaeous; columella, stipe, or sterile base none; peridium usually thin and fragile, simplex, white; gleba white or slightly yellowish; cavities filled with hyphae bearing spores terminally on short branches; septa thin, homogeneous; spores echinate or reticulate at maturity, surrounded by a gelatinous sheath, globose, resembling those of *Leucogaster*.

From our study of the young stages of *Leucogaster floccosus* Hesse (p. 390), it seems probable that eventually *Leucophlebs* will be recognized as the chlamydosporic condition of *Leucogaster*, or retained as a hypogaeous genus of the *Fungi Imperfecti*.

1. Leucophlebs magnata Harkness, Cal. Acad. Sci. Proc. Bot. III. **1**: 257–258. 1899; Roumeguère, Rev. Myc. **22**: 83. 1900; Saccardo & Sydow in Sacc. Syll. Fung. **16**: 252. 1902.

Illustrations: Harkness, Cal. Acad. Sci. Proc. Bot. III. **1**: *pl. 42. f. 7a–7c;* Rev. Myc. **22**: *pl. 204. f. 6–8.*

Type: cotype in Dudley Herb. at Leland Stanford Jr. Univ.

Fructification 3 cm. in diameter, subglobose or elongate, white, smooth; peridium 120–150 μ thick, composed of fine, thick-walled, closely woven hyphae, white; gleba white, the freshly cut surface showing a blue tint which soon vanishes; cavities decreasing in size toward the surface, full of cobwebby hyphae like a capillitium; septa thin, homogeneous, 60–80 μ thick, composed of closely woven, hyaline hyphae; spores borne terminally on long slender branches of the cavity hyphae, hyaline, spherical, echinate, enclosed in a gelatinous sheath, 13 μ in diameter.

Under *Acer* and *Quercus*. Oregon to California. April and May.

In Harkness, 100b, crystalline matter is found in the peridium and in Harkness, 154b, the spores become quite thick-walled. The spines on the spores are arranged in rows, giving the appearance shown by Harkness (*l.c., f. 7c*) when not quite in focus.

Specimens examined:

[1] Committee on Nomenclature of the Botanical Society of America. Report. Bot. Soc. Am. Publ. **73**: 70–71. 1919 (see p. 71).

Oregon: Corvallis, *L. M. Boozer* (in Oregon Agr. Coll. Herb. 4831, 4832, and Zeller Herb. 2323, 2324, and in Dodge Herb. 2073, 2074).

California: *H. W. Harkness, 100b, 154b;* Napa County, Calistoga, *H. W. Harkness, 154,* cotype (all in Dudley Herb. at Leland Stanford Jr. Univ.).

2. Leucophlebs candida Harkness, Cal. Acad. Sci. Proc. Bot. III. **1**: 258. 1899; Roumeguère, Rev. Myc. **22**: 83. 1900; Saccardo & Sydow in Sacc. Syll. Fung. **16**: 252. 1902.

Type: cotype in Dudley Herb. at Leland Stanford Jr. Univ.

Fructifications 2 cm. in diameter, irregular, white, surface studded with shallow depressions; peridium 15–20 μ thick, homogeneous with the septa; gleba white, becoming yellowish in alcohol; cavities filled with branched hyphae which bear spores terminally on the branches; septa thin; spores hyaline, spherical, reticulate at maturity, enclosed in a gelatinous sheath, 8 μ in diameter.

California. June.

The cotype of this species is so badly parasitized that its structure is very difficult to make out.

Specimens examined:

California: Marin County, Mill Valley, *H. W. Harkness, 207,* cotype (in Dudley Herb. at Leland Stanford Jr. Univ.).

3. Hydnangium liospermum Tulasne, Fung. Hypog. 76. 1851; DeToni in Saccardo, Syll. Fung. **7**: 176. 1888; Hesse, Hypog. Deutschl. **1**: 84. 1891.—*Octaviania liosperma* Lloyd, Myc. Notes **67**: 1141. 1923.

Illustrations: Tulasne, Fung. Hypog. *pl. 21. f. 1.*

Type: location unknown to us.

Fructification small (size of a pea), firm, globose, white, with a slight, sterile base, here and there enveloped in a white floccose mycelium separating in places; peridium thick, homogeneous, not separable, white, continuous with the septa; gleba firm, light ochraceous to apricot color; cavities unequal in size, narrow-oblong, radiating from the center to the periphery; septa mucous-cartilaginous, gray, hyaline by transmitted light, variable in

thickness, some arising from the base much thicker than others, homogeneous, of large, closely woven hyphae; spores borne terminally, mostly on 2-celled branches, globose, small, 6.5 μ in diameter, smooth, thick-walled.

Under fallen leaves in oak woods, almost epigaeous. Not far from Orleans (Parc de Beauvoir near Brivodurum). Autumn.

Hesse referred here a specimen in the Danziger Museum collected by Bail in Kreis Schwetz near Teufelsstein, October, 1878. From the above description it seems quite likely that this species is to be referred to *Leucophlebs*, where the small spores, yellow gleba, radiating elongated cavities, and rudimentary columella should serve to distinguish it from other members of this genus. However, we prefer not to make the transfer until we have the opportunity to study authentic material.

Explanation of Plate

PLATE 11

Fig. 1. *Leucogaster rubescens* Zeller & Dodge.
a. Section of peridium and septa showing pseudoparenchyma of the peridium, sections of fibrils on the surface, and the 4-spored basidia. Young material, × 150.
b. Young and mature basidium and spores, × 500.
c. Basidiospore showing the echino-reticulate character of the surface with gelatinous sheath, × 750.

Fig. 2. *Leucogaster araneosus* Zeller & Dodge.
a. Section of fibrous peridium and relation of septa showing the 4-spored basidia. Young material, × 150.
b. Basidia, × 500.
c. Basidiospore showing the alveolate-reticulate character of the surface, with blunt spines projecting from the angles of the alveoli and gelatinous sheath, × 1000.

Fig. 3. *Leucogaster luteomaculatus* Zeller & Dodge.
a. Section showing the duplex character of the peridium (the outer partly sloughed off), the scissile septum and basidia, × 150.
b. Basidia, × 500.
c. Basidiospore showing the verrucose character of the surface with gelatinous sheath, × 1000.

Fig. 4. *Leucogaster fulvimaculosus* Zeller & Dodge.
a. Section showing the thick peridium, with portion of fibril on surface, septa, definite layer of basidial stalks embedded in a gelatinous layer within the cavities and the basidiospores lining the cavities, × 150.
b. Basidia showing the typical 3-spored tips, × 500.
c. Basidiospore showing the simple reticulate surface with gelatinous sheath, × 750.

Fig. 5. Basidiospore of *Leucogaster odoratus* (Harkn.) Zeller & Dodge, × 750.

Fig. 6. Basidiospore of *Leucogaster foveolatus* (Harkn.) Zeller & Dodge, × 750.

Fig. 7. Basidiospores of *Leucogaster citrinus* (Harkn.) Zeller & Dodge.
a. Mature spore, × 750.
b. Young spore, × 750.

Fig. 8. Basidiospore of *Leucogaster anomalus* (Peck) Zeller & Dodge, showing the pitted surface, × 750.

Fig. 9. Basidiospore of *Leucogaster badius* Matt. showing the pitted surface, × 750.

Fig. 10. Basidiospore of *Leucogaster floccosus* Hesse, showing the echinulate-reticulate character of the exospore and thick gelatinous sheath, × 750.

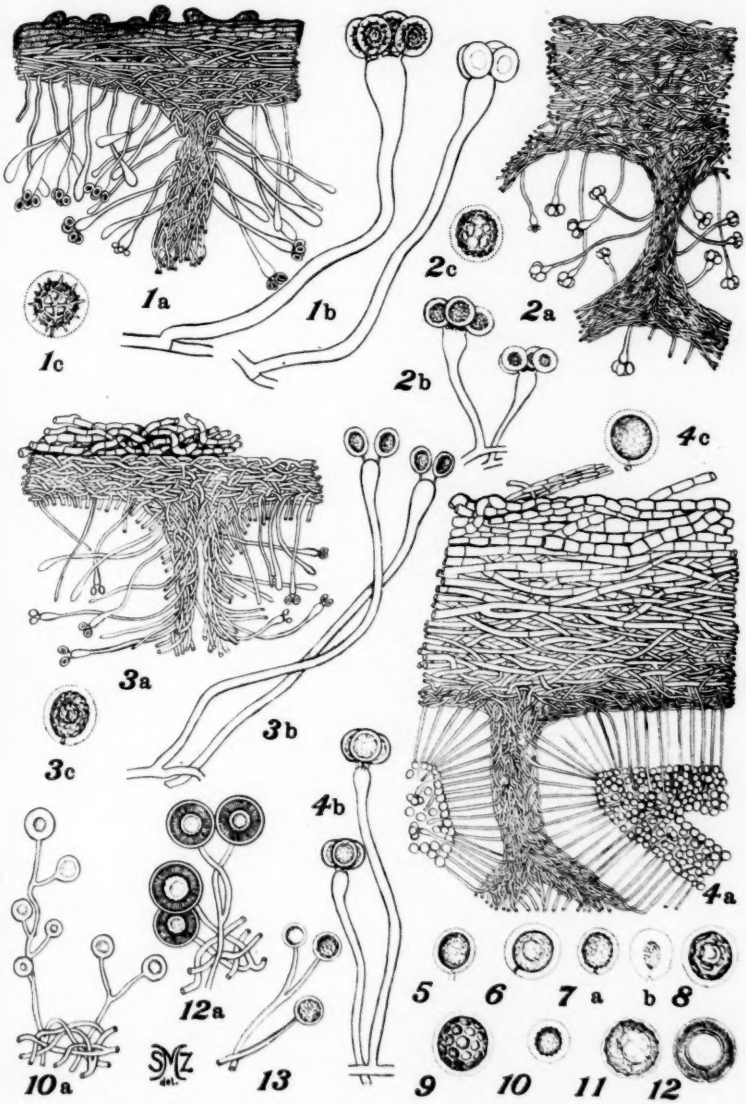
Fig. 10a. The conidia from young cavities of *Leucogaster floccosus*. This conidial stage cannot be distinguished from *Leucophlebs* Harkness, × 500.

Fig. 11. Basidiospore of *Leucogaster Tozziana* (Cav. & Sacc.) Matt., × 750.

Fig. 12. Conidium of *Leucophlebs magnata* Harkn. showing the peculiar markings in median view, × 750.

Fig. 12a. Shows the conidia and conidiophores of *L. magnata*, × 500.

Fig. 13. Conidia and conidiophores of *Leucophlebs candida* Harkn., × 500.



ZELLER AND DODGE—LEUCOGASTER AND LEUCOPHLEBS

VARIATION AND CORRELATION IN THE INFLORESCENCE OF MANFREDA VIRGINICA

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I. Introduction

The purpose of this paper, which is one of a series on the general problem of the physiology of fertility in plants, is to present the results of a biometric study of variation and correlation in the inflorescences of *Manfreda virginica*.

This study was planned, the materials collected, and practically all the tabulations made at the Missouri Botanical Garden in 1906 and 1907.[1] The calculations were, in large part, carried out in the Biometric Laboratory at University College, London, in 1908. The long delay in completing the manuscript for publication has been in part due to pressure of other work and in part to an effort to secure formulae to deal more effectively with certain phases of the problem.

The points to be especially considered are:—

1. The variability and correlation of the same species when growing in different habitats.
2. The correlation between the number of flowers produced and the number of capsules developing, and between the number of flowers and capsules produced and the number of seeds developing.
3. The relationship between position of the flower on the inflorescence and fruit production.
4. The correlation between position of the flower on the inflorescence and the number of seeds per locule and per fruit.
5. The correlation between the position of the fruit on the inflorescence and the number of seeds per locule and per fruit.
6. The correlation between the number of seeds in the 3 locules of the fruit.

[1] The initial stages of the work were aided by a grant from the American Association for the Advancement of Science.

II. MATERIALS

The inflorescence of *M. virginica* is a favorable subject for work on the problem of fertility. Since all the flowers are arranged on a single axis, it is easy to consider the influence of position on the inflorescence upon the chances of development of the fruit and upon the characteristics of the matured fruit. The flowers which fail to produce fruits leave a conspicuous scar, so that the number of flowers produced may be accurately determined. The ripened seeds have a fine black color and are easily counted. Unfortunately it is impossible to determine the number of ovules formed. The trimerous nature of the fruit makes possible the consideration of certain problems concerning the interrelationship of numbers of seeds per locule.

Collections of material were taken from 2 different localities. The first was the more open woods at Meramec Highlands, near St. Louis. The second was the edge of the limestone cliffs along the Mississippi River, south of Jefferson Barracks, Mo.

In the absence of quantitative criteria no attempt will be made to distinguish in any precise way between the conditions for plant growth in these 2 habitats. The general impression conveyed by an examination of the two habitats was that growth at Meramec Highlands was much more luxuriant than that on the crests of the cliffs south of Jefferson Barracks.

The countings made comprise the following:—

1. Number of flowers per inflorescence (*f*).
2. Number of capsules matured per inflorescence (*c*).
3. The actual position of the capsule on the inflorescence (*p*). This is the position of the flower measured from the proximal end of the inflorescence. Thus the position of the first flower is 1, while that of the terminal flower is measured by the number of flowers produced on the inflorescences.
4. Relative position of the capsule (*r*). This measures the position of the individual capsule in the series produced by an inflorescence. Thus the relative position of the lowermost capsule will be 1, whatever the position of the flower which produced it, while that of the most distal capsule will be the same as the number of capsules produced by the inflorescence in question.

5. Number of seeds per locule (*s*).

The symbols in parentheses are those used to designate the several characters in the formulae.

The heavy work of counting the number of seeds per locule was carried out in only 1100 inflorescences or 18774 locules. Number of flowers and number of capsules was determined in a larger number of inflorescences, 3425 in all.

For convenience of reference the series of material are designated as follows:—

I. Three hundred inflorescences, Meramec Highlands, 1906. Seeds counted.

II. Two hundred fifty inflorescences, below Jefferson Barracks, 1906. Seeds counted.

III. One thousand inflorescences, below Jefferson Barracks, 1906. Flowers and fruits only counted.

IV. Three hundred inflorescences, Meramec Highlands, 1907. Seeds counted.

V. Three hundred five inflorescences, Meramec Highlands, 1907. Flowers and fruits only counted.

VI. Two hundred fifty inflorescences, below Jefferson Barracks, 1907. Seeds counted.

VII. One thousand twenty inflorescences, below Jefferson Barracks, 1907. Flowers and fruits only counted.

In studies involving only the number of flowers and number of fruits per inflorescence series II and III can be treated together; series IV can be combined with series V; and series VI added to series VII for the purpose of securing larger and smoother distributions. In respect to these characters series IV and V and series VI and VII should show only the differences due to random sampling, since practically all the material for each of the pairs was taken at one time and a subsample was drawn at random for the seed countings.

The lot of material from the Jefferson Barracks locality for 1907 is not strictly comparable with that for 1906 in one respect. The plants from which the countings of the number of seeds per locule were made in 1906 were collected all along the bluffs from Jefferson Barracks to a point above Cliff Cave. In 1907 the material from which the countings of seed number were made was taken

TABLE I

FREQUENCY DISTRIBUTION OF NUMBER OF FLOWERS PER INFLORESCENCE WITH TOTAL NUMBER OF FRUITS AND SEEDS PRODUCED BY EACH CLASS OF INFLORESCENCE IN 4 SERIES IN WHICH NUMBER OF SEEDS PER LOCULE WAS DETERMINED

Flowers	J. B. 1906			J. B. 1907			M. H. 1906			M. H. 1907		
	f	Fruits	Seeds	f	Fruits	Seeds	f	Fruits	Seeds	f	Fruits	Seeds
2	1	1	47	—	—	—	—	—	—	—	—	—
6	1	2	58	—	—	—	—	—	—	—	—	—
7	1	4	148	—	—	—	—	—	—	1	1	43
8	—	—	—	—	—	—	—	—	—	1	2	73
9	1	2	67	—	—	—	1	2	82	1	1	27
10	—	—	—	1	7	85	—	—	—	—	—	—
11	2	6	193	—	—	—	—	—	—	1	7	66
12	3	8	220	—	—	—	1	3	154	—	—	—
13	1	2	56	2	4	138	2	6	163	4	13	291
14	7	20	593	5	13	452	2	5	147	—	—	—
15	8	21	664	2	6	323	1	4	156	6	21	769
16	9	29	960	6	24	807	2	7	221	7	21	917
17	15	37	1141	11	50	1681	4	14	658	6	21	778
18	12	43	1335	12	39	1511	6	26	1152	10	39	1640
19	17	60	1435	6	26	941	8	35	1505	16	59	2552
20	15	64	1676	11	43	1400	10	40	1452	12	47	1557
21	25	104	2764	6	24	686	14	59	2441	11	50	2012
22	18	79	2291	14	65	2389	10	42	1559	19	79	3279
23	12	51	1196	18	93	2918	7	36	1443	4	15	655
24	8	33	1077	14	68	2118	12	65	2612	13	73	2765
25	14	60	2003	15	82	2320	13	75	3071	15	79	2752
26	9	53	1469	11	62	2152	15	88	3722	16	86	3413
27	11	45	1654	14	74	2320	18	124	5353	16	83	2799
28	6	23	462	7	33	1067	17	103	4365	14	78	3339
29	7	37	878	5	30	1038	11	57	2399	13	80	2829
30	6	30	1234	7	44	1440	13	90	3819	9	60	2175
31	1	4	147	6	30	1026	18	128	5109	14	94	2942
32	6	37	1570	8	54	1852	6	42	1840	14	84	3419
33	4	22	767	9	61	1890	16	129	5237	7	47	1621
34	5	44	1628	9	65	2059	12	114	5059	13	92	3932
35	4	26	1084	12	77	2640	17	127	4510	10	83	3426
36	6	39	1584	5	28	938	9	73	2859	6	48	1536
37	2	16	462	6	51	1310	7	57	2343	6	47	1854
38	4	27	894	2	18	762	3	20	891	4	33	1292
39	1	7	263	4	28	903	5	41	1556	5	55	2152
40	1	8	345	3	17	607	6	50	2436	5	44	1715
41	1	10	227	3	25	684	3	31	1183	4	32	1134
42	1	11	355	3	25	938	7	70	3027	3	27	906
43	2	17	662	2	31	828	1	9	360	3	28	1113
44	—	—	—	3	17	609	2	13	510	4	32	1592
45	1	10	222	3	30	692	5	55	2345	1	8	428
46	—	—	—	3	32	1318	3	33	1251	1	13	453
47	1	16	454	1	10	356	1	9	256	—	—	—
48	—	—	—	—	—	—	5	47	2028	—	—	—
49	—	—	—	—	—	—	1	7	337	—	—	—
50	1	12	326	—	—	—	—	—	—	—	—	—
51	—	—	—	—	—	—	—	—	—	2	22	1188
52	—	—	—	—	—	—	—	—	—	—	—	—
53	—	—	—	—	—	—	1	12	388	1	13	465
54	—	—	—	—	—	—	3	41	2150	—	—	—
55	—	—	—	—	—	—	2	28	1178	—	—	—
60	—	—	—	1	6	195	—	—	—	—	—	—
61	—	—	—	—	—	—	—	—	—	2	20	655

entirely from the vicinity of Cliff Cave. The 1000 stalks taken in 1906 for countings of flowers and fruits only and the entire series of 1270 inflorescences taken in 1907 are therefore directly comparable as samples of the same species from the same locality for 2 years.

III. Presentation and Analysis of Data

1. TYPE AND VARIATION IN DIFFERENT HABITATS

In this section we have to consider the frequency distributions of number of flowers and fruits per inflorescence, and the number of seeds matured per locule and per fruit.

In doing this we shall hope to replace the impression of chaotic disorder which must be the result of mere inspection in the field by a definite mental picture of the orderliness which prevails in the frequencies of the numbers of flowers and fruits, in the position of insertion of the fruits, and in the number of seeds per locule and per fruit.

The frequency distribution of number of flowers per inflorescence in the 4 series in which the number of seeds was determined is shown in table I.[1] For the 3 other series, in which flowers and fruits only were counted, the reader must consult table II.

Because of the wide range of variation in number of flowers per inflorescence, very irregular graphs are obtained if the ungrouped frequencies are plotted. Grouping in classes of 3-units range and reducing to percentage frequencies we have the distributions for the two habitats represented in fig. 1 for 1906 and in fig. 2 for 1907. In 1906 the results for Meramec Highlands (N = 300) and Jefferson Barracks (N = 1250) are not in good agreement. The distribution for Meramec Highlands is particularly irregular, but this is doubtless due in large part to the fact that this series comprises only 300 inflorescences—less than one quarter the number from Jefferson Barracks. In 1907 the distributions represent 605 inflorescences for Meramec Highlands and 1270 for Jefferson Barracks, and are in much closer agreement.

[1] The frequencies of inflorescences with varying numbers of flowers are alone required here. The total fruits and total seeds which are also given will be used for the determination of correlations in a subsequent section.

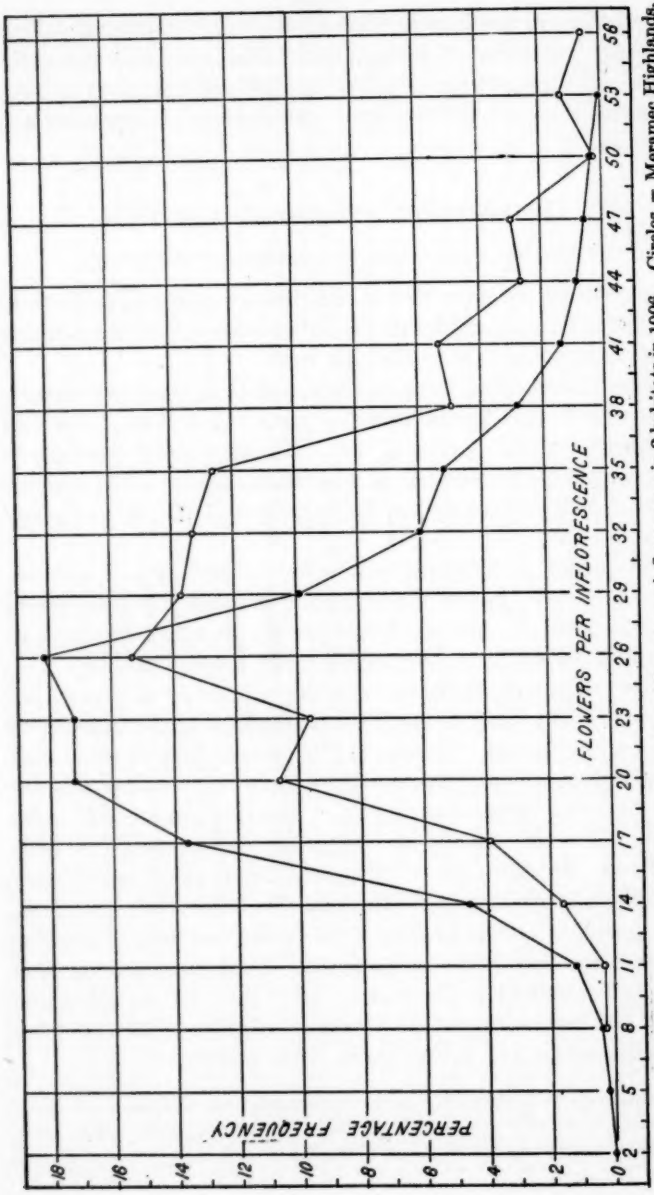

Fig. 1. Percentage frequency distribution of number of flowers per inflorescence in 2 habitats in 1906. Circles = Meramec Highlands, solid dots = Jefferson Barracks.

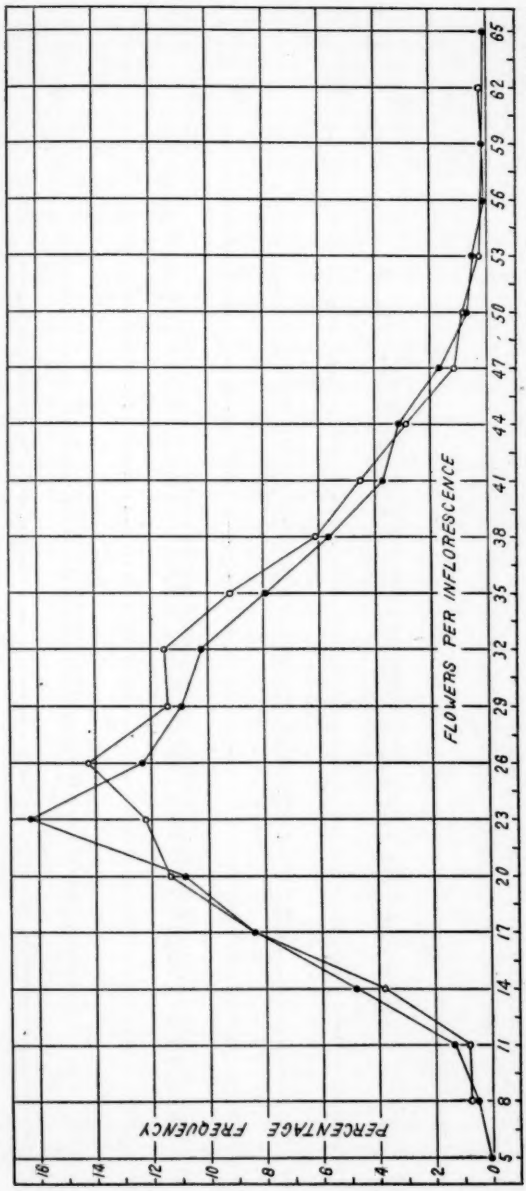

Fig. 2. Percentage frequency distribution of number of flowers per inflorescence in 2 habitats in 1907. Circles = Meramec Highlands, solid dots = Jefferson Barracks.

TABLE II

FREQUENCY DISTRIBUTION OF NUMBER OF FLOWERS PER INFLORESCENCE AND TOTAL NUMBER OF FRUITS ON EACH CLASS OF INFLORESCENCE IN 3 SERIES IN WHICH FLOWERS AND FRUITS ONLY WERE COUNTED

Flowers	J. B. 1906		J. B. 1907		M. H. 1907	
	f	Fruits	f	Fruits	f	Fruits
4	1	2	—	—	—	—
6	—	—	1	2	—	—
7	2	4	2	5	—	—
8	—	—	1	2	—	—
9	1	1	4	11	1	2
10	1	2	2	2	—	—
11	5	13	4	12	2	6
12	3	8	9	26	2	4
13	11	31	18	50	2	6
14	14	39	19	70	5	15
15	17	49	15	51	6	15
16	42	140	30	116	8	34
17	43	160	22	87	5	20
18	49	190	26	108	15	56
19	53	209	39	167	7	33
20	51	208	39	170	10	47
21	54	239	37	162	12	48
22	59	262	66	340	16	78
23	54	258	52	246	5	28
24	64	327	43	227	17	86
25	58	312	46	276	14	72
26	58	364	30	172	18	105
27	78	415	40	248	7	39
28	36	226	46	285	13	72
29	36	260	43	296	10	51
30	33	219	31	212	10	69
31	24	180	36	302	14	94
32	23	156	30	218	10	66
33	17	111	41	290	11	71
34	19	146	25	204	16	106
35	16	117	23	184	6	46
36	15	111	27	236	5	42
37	9	69	23	190	7	48
38	10	99	16	146	10	75
39	9	87	22	196	5	42
40	6	48	11	99	7	69
41	5	48	13	131	6	52
42	4	36	15	137	2	22
43	3	31	10	115	4	35
44	2	9	11	113	2	22
45	3	32	12	131	4	21
46	5	54	9	92	1	18
47	—	—	4	50	2	21
48	2	23	7	100	3	44
49	—	—	3	43	3	36
50	2	23	3	31	—	—
51	2	32	3	34	—	—
52	—	—	4	46	—	—
53	—	—	2	22	1	20
54	1	11	1	14	—	—
56	—	—	1	12	—	—
57	—	—	1	19	—	—
58	—	—	—	—	—	—
59	—	—	1	9	1	13
66	—	—	1	27	—	—

TABLE III

STATISTICAL CONSTANTS FOR NUMBER OF FLOWERS PER INFLORESCENCE

Series	N	Mean	Standard deviation	Coefficient of variation
Meramec Highlands 1906 (I)	300	29.9467±.3304	8.4859±.2337	28.3367±0.8406
Meramec Highlands 1907 (IV)	300	27.6100±.3294	8.4592±.2330	30.6381±0.9195
Meramec Highlands 1907 (V)	305	28.2721±.3441	8.9098±.2433	31.5144±0.9422
Meramec Highlands 1907 (IV)+(V)	605	27.9438±.2384	8.6956±.1686	31.1181±0.6592
Jefferson Barracks 1906 (II)	250	23.4760±.3196	7.4929±.2260	31.9172±1.0561
Jefferson Barracks 1906 (III)	1000	24.7480±.1502	7.0461±.1062	28.4716±0.4628
Jefferson Barracks 1906 (II)+(III)	1250	24.4936±.1365	7.1558±.0965	29.2148±0.4260
Jefferson Barracks 1907 (VI)	250	27.2360±.3519	8.2479±.2488	30.2832±0.9935
Jefferson Barracks 1907 (VII)	1020	27.6078±.1943	9.2020±.1373	33.3312±0.5500
Jefferson Barracks 1907 (VI)+(VII)	1270	27.5346±.1708	9.0234±.1207	32.7711±0.4832

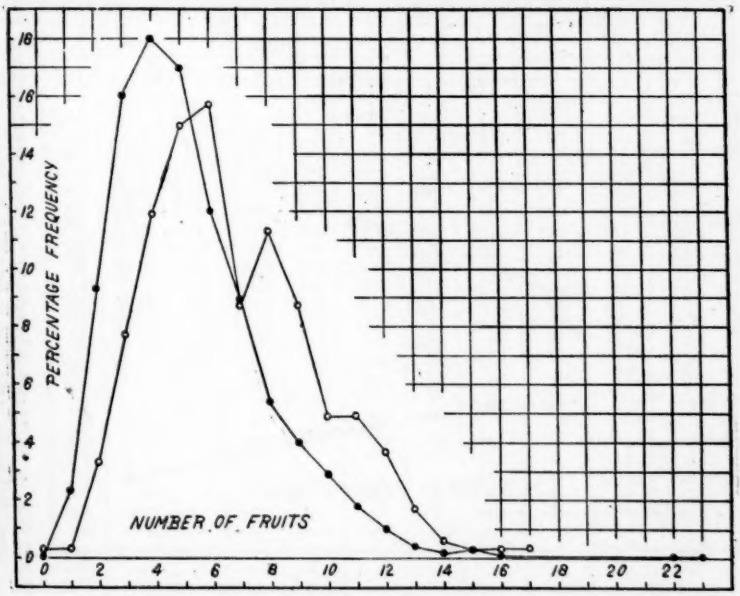

Fig. 3. Percentage frequency distribution of number of fruits per inflorescence in 2 habitats in 1906. Circles = Meramec Highlands, solid dots = Jefferson Barracks.

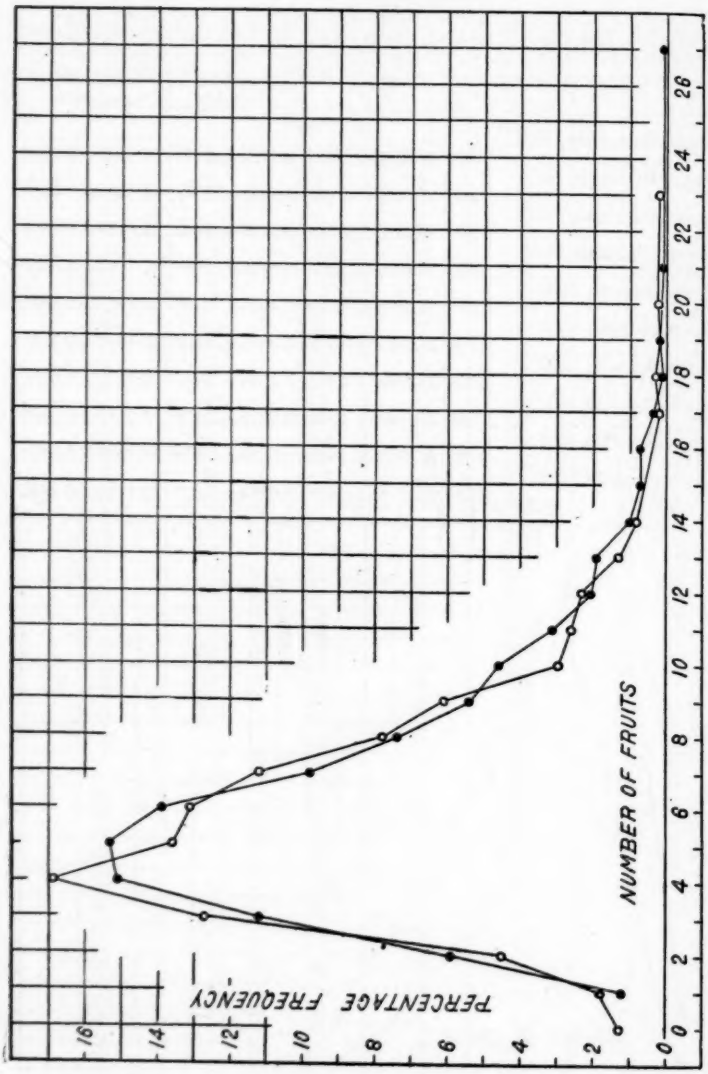

Fig. 4. Percentage frequency distribution of number of fruits per inflorescence in 2 habitats in 1907. Circles = Meramec Highlands, solid dots = Jefferson Barracks.

The fundamental variation constants, means, standard deviations and coefficients of variation of number of flowers per inflorescence in the several series of materials appear in table III. These will be discussed in comparison with those for number of fruits per inflorescence.

The frequency distribution of number of fruits per inflorescence in the 7 series of materials is shown in table IV. Series I, II + III, IV + V, and VI + VII have been reduced to percentage frequencies and are represented graphically in fig. 3 for 1906 and fig. 4 for 1907.

With the exception of the Meramec Highlands series for 1906, in which the number of observations is only 300, the frequencies

TABLE IV

FREQUENCY DISTRIBUTIONS OF NUMBER OF FRUITS PER INFLORESCENCE IN 7 SERIES AND TOTAL SEEDS PRODUCED ON EACH CLASS OF INFLORESCENCE IN 4 SERIES IN WHICH NUMBER OF SEEDS WAS DETERMINED

Fruits	J. B. 1906 II		J. B. 1907 VI		M. H. 1906 I		M. H. 1907 IV		Series III	Series VII	Series V
	f	Seeds	f	Seeds	f	Seeds	f	Seeds	f	f	f
0	—	—	—	—	—	—	—	—	—	—	5
1	14	428	5	171	1	17	7	348	15	10	4
2	68	2427	28	957	20	985	24	991	82	61	15
3	165	5317	111	4367	69	3033	120	5138	145	105	37
4	184	5807	172	5682	144	5941	208	8521	179	149	50
5	155	4834	210	7198	225	9183	180	7399	183	152	46
6	126	4130	210	7128	282	12503	264	9620	129	141	35
7	105	2974	196	6184	183	7565	231	8067	96	96	35
8	96	3282	112	3255	272	10818	200	7229	55	80	22
9	54	1341	90	2525	234	9317	171	6727	44	59	18
10	50	2060	70	2497	150	6612	100	3616	28	51	8
11	33	991	66	2115	165	6658	44	1505	20	34	12
12	24	566	48	1329	132	4960	108	4239	10	22	5
13	—	—	26	685	65	2605	52	2028	5	22	4
14	—	—	14	579	28	1087	28	1126	2	11	3
15	—	—	—	—	15	621	—	—	4	9	—
16	16	454	16	328	16	641	—	—	1	8	—
17	—	—	—	—	16	781	—	—	—	4	1
18	—	—	18	398	—	—	—	—	—	1	2
19	—	—	—	—	—	—	—	—	—	3	1
20	—	—	—	—	—	—	—	—	—	—	1
21	—	—	—	—	—	—	—	—	—	1	—
22	—	—	—	—	—	—	—	—	1	—	—
23	—	—	—	—	—	—	—	—	1	—	1
24	—	—	—	—	—	—	—	—	—	—	—
25	—	—	—	—	—	—	—	—	—	—	—
26	—	—	—	—	—	—	—	—	—	—	—
27	—	—	—	—	—	—	—	—	—	1	—

form very smooth distributions. In all, a conspicuous skewness, a tendency to tail off in the direction of the larger number of fruits, is a characteristic feature.

The physical constants for number of fruits per inflorescence are shown for all the series in table v.

The first question concerning the statistical constants of both flowers and fruits which requires consideration is that of the difference between the means of the series for the different years in the same habitat and for the different habitats. The comparisons may be based upon the combination series in so far as these are

TABLE V

STATISTICAL CONSTANTS FOR NUMBER OF FRUITS PER INFLORESCENCE

Series	N	Mean	Standard deviation	Coefficient of variation
Meramec Highlands 1906 (I)	300	6.7233±.1134	2.9109±.0802	43.2958±1.3980
Meramec Highlands 1907 (IV)	300	5.7900±.1073	2.7554±.0759	47.5900±1.5798
Meramec Highlands 1907 (V)	305	6.0623±.1297	3.3593±.0917	55.4123±1.9226
Meramec Highlands 1907 (IV)+(V)	605	5.9273±.0843	3.0777±.0596	51.9247±1.2490
Jefferson Barracks 1906 (II)	250	4.4800±.1076	2.5222±.0761	56.2995±2.1704
Jefferson Barracks 1906 (III)	1000	5.3610±.1143	2.6162±.0808	48.8012±0.8941
Jefferson Barracks 1906 (II)+(III)	1250	5.1848±.0500	2.6215±.0353	50.5611±0.8378
Jefferson Barracks 1907 (VI)	250	5.5680±.1156	2.7095±.0817	48.6619±1.7815
Jefferson Barracks 1907 (VII)	1020	6.4059±.0701	3.3237±.0496	51.8852±0.9608
Jefferson Barracks 1907 (VI)+(VII)	1270	6.2409±.0611	3.2293±.0432	51.7442±0.8579

TABLE VI

COMPARISON OF THE STATISTICAL CONSTANTS FOR THE 2 DIFFERENT YEARS FOR PLANTS GROWING IN THE SAME HABITAT

Difference 1906 less 1907	Mean	Standard deviation	Coefficient of variation
Meramec Highlands			
Flowers	+2.0029±.4074	−0.2097±.2882	−2.7814±1.0682
Fruits	+0.7960±.1413	−0.1668±.0999	−8.6289±1.8747
Jefferson Barracks			
Flowers	−3.0410±.2186	−1.8676±.1545	−3.5563±0.6442
Fruits	−1.0561±.0790	−0.6078±.0558	−1.1831±1.1991

available. Thus in comparing the results for the 2 years in the same habitat we may determine the differences between the means for series I and series IV + V for Meramec Highlands and for series II + III and series VI + VII for Jefferson Barracks. The differences for the two years are given in table VI, which shows that the average number of flowers and fruits is slightly, but significantly, higher at Meramec Highlands in 1906 than in 1907, whereas the reverse is true at Jefferson Barracks. The variabilities, both absolute (S. D.) and relative (C. V.) are higher for both flowers and fruits in both habitats in 1907 than in 1906.

We now have to consider the difference in the inflorescsence produced in the 2 habitats in the same year. The differences may be taken (Meramec Highlands) less (Jefferson Barracks).

The differences in table VII are obtained by comparing the results for series I (Meramec Highlands) and series II + III (Jefferson Barracks) for 1906, and for series IV + V (Meramec Highlands) and series VI + VII (Jefferson Barracks) for 1907. The differences in this table show that in both years the number

TABLE VII

COMPARISON OF THE STATISTICAL CONSTANTS FOR PLANTS GROWING IN THE DIFFERENT HABITATS IN THE SAME YEAR

Difference	Mean	Standard deviation	Coefficient of variation
1906			
Flowers	+5.4531±.3575	+1.3301±.2528	−0.8781±0.9424
Fruits	+1.5385±.1239	+0.2894±.0876	−7.2653±1.6298
1907			
Flowers	+0.4092±.2933	−0.3278±.2074	−1.6530±0.8173
Fruits	−0.3136±.1041	−0.1516±.0736	+0.1805±1.5153

of flowers is larger at Meramec Highlands than at Jefferson Barracks. The difference in 1907 is, however, insignificant. The number of fruits is slightly higher at Meramec Highlands in 1906 but slightly lower in 1907. The results of this comparison show that the differences between the 2 habitats are either nil or much smaller than would have been anticipated from a mere inspection of the 2 habitats.

We now turn to the question of relative values of the constants for number of flowers and number of fruits per inflorescence.

Comparing the mean number of flowers and fruits as given in tables III and V, we note that the average flower number ranges from 23.5 to 29.9, whereas the mean number of fruits range from 4.5 to 6.7. Thus only about 20 per cent of the flowers develop into fruits.

We also require some measure of the relative fruit production of the several series.

For this purpose we may make use of the coefficient of fecundity (Harris, '10), i. e., the ratio $\bar{c}/\bar{f}$.[1]

The coefficients are given in table VIII, which shows that about 22 per cent of the flowers develop into fruits. The probable errors are low, and the differences between the several series are

TABLE VIII

COEFFICIENTS OF FECUNDITY IN THE 4 SERIES

Series	Number of inflorescences	Coefficient of fecundity
Meramec Highlands 1906	300	.2245±.0030
Meramec Highlands 1907	605	.2121±.0021
Jefferson Barracks 1906	1250	.2117±.0016
Jefferson Barracks 1907	1270	.2267±.0015

possibly significant in comparison with their probable errors. The actual magnitude of the differences is, however, very small, being .0124 ± .004 for the 2 Meramec Highlands series, .0150 ± .002 for the 2 Jefferson Barracks series, .0128 ± .003 for the series from the 2 habitats in 1906, and .0146 ± .003 for the series from the 2 habitats in 1907.

The standard deviations as given in tables III and V for number of flowers range from 7.0 to 9.2, whereas those for number of fruits vary from 2.5 to 3.4 in the several series. The significance of the differences between the several lots of material has been discussed above. The absolute variability (standard deviation) of number of fruits per inflorescence is much smaller than that for number of flowers per inflorescence. In general the fruits are about one-third the comparable values for the flowers.

[1] The probable error of C. F., the coefficient of fecundity, is given by

$$.67449\sqrt{c \times (1-c/f)/f}.$$

The great difference in the mean number of flowers and fruits renders a discussion of the comparison of variability impossible except on the basis of constants involving correction for mean numbers. These constants are afforded by the coefficients of variation which show that the variation for number of fruits per inflorescence is regularly higher than that for number of flowers per inflorescence. The coefficients of variation for number of flowers range from 28.3 to 33.3, whereas those for number of fruits range from 43.3 to 56.3.

This result for relative variability in flower and fruit number is substantiated by results for *Crinum longifolium* and *Celastrus scandens*, but not for *Staphylea trifolia*. The actual coefficients are as follows:

	Flowers	Fruits
Crinum longifolium (Harris, 1912 a)	22.80-24.32	31.73-33.70
Celastrus scandens (Harris, 1909)	26.80	48.58
Staphylea trifolia (Harris, 1909 a)	64.44	53.04

In a series of inflorescences of varying numbers of flowers per inflorescence the distribution of the position of the flowers on the inflorescence must be considered in relation to the number of flowers in each position, the ovaries of which might have developed into capsules.

Table IX shows the number of flowers formed and the number of capsules matured in the various positions on the inflorescence for 3 of the series of data.[1] From these data the percentage frequencies of numbers of capsules matured in each position on the inflorescence have been derived and are represented in fig. 5. The higher positions, of course, occur only on the larger inflorescences. In any sample which it is practicable to secure, the numbers of flowers and fruits in the more distal positions are so small that percentages calculated upon them are very irregular. Only percentages based upon at least 100 flowers have been included in the diagram.

[1] The reader who cares to do so may determine the number of flowers and number of fruits for the 3 series of inflorescences in which number of flowers and number of fruits only was determined by subtracting the appropriate sections of table X from table IX.

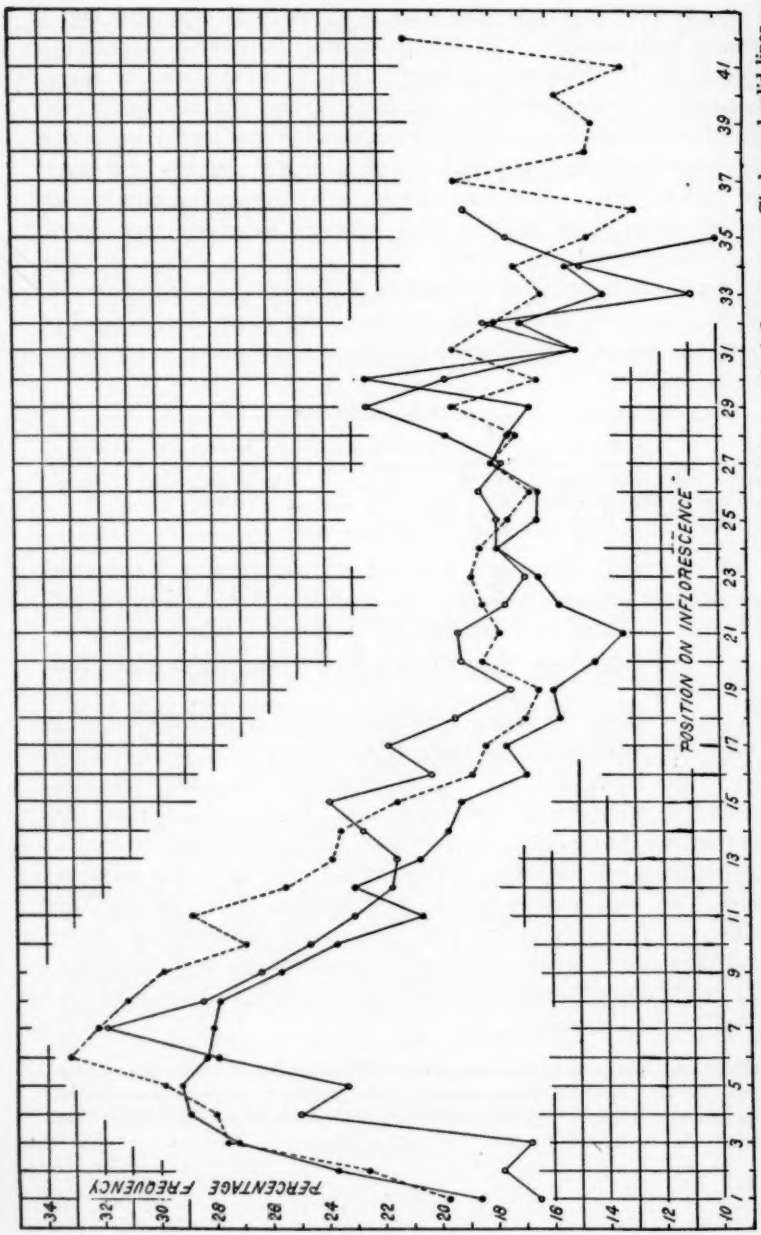

Fig. 5 Percentage frequencies of flowers which develop into fruits in various positions on the inflorescence. Circles and solid lines = Meramec Highlands, 1907; solid dots and solid lines = Jefferson Barracks, 1906; solid dots and broken lines = Jefferson Barracks, 1907.

The 3 series of countings represented in the diagrams show essential agreement in that the relative number of capsules developing in the most proximal position is low. It increases rapidly to a maximum on about the sixth position. It then declines rapidly to about 17 per cent in the twentieth position, after which it remains about the same throughout the remainder of the inflorescence.[1]

TABLE IX

NUMBER OF FLOWERS AND FRUITS PRODUCED AT VARIOUS POSITIONS ON THE INFLORESCENCE IN 3 SERIES IN WHICH FLOWERS AND FRUITS ONLY WERE COUNTED

P	J. B. 1906		J. B. 1907		M. H. 1907		P	J. B. 1906		J. B. 1907		M.H. 1907	
	Fl.	Fr.	Fl.	Fr.	Fl.	Fr.		Fl.	Fr.	Fl.	Fr.	Fl.	Fr.
1	1250	233	1270	251	605	100	34	143	22	308	53	155	23
2	1250	297	1270	287	605	108	35	119	12	274	40	126	22
3	1249	340	1270	351	605	102	36	99	18	239	31	110	21
4	1249	362	1270	356	605	152	37	78	12	207	40	99	13
5	1248	364	1270	379	605	141	38	67	15	178	26	86	15
6	1248	354	1270	422	605	169	39	53	12	160	23	72	13
7	1247	351	1269	409	605	193	40	43	6	134	21	62	12
8	1244	348	1267	395	604	172	41	36	5	120	16	50	10
9	1244	320	1266	378	603	159	42	30	8	104	22	40	10
10	1242	294	1262	339	601	148	43	25	6	86	18	35	7
11	1241	256	1259	361	601	139	44	20	5	74	12	28	9
12	1234	285	1255	321	598	130	45	18	1	60	12	21	5
13	1228	255	1246	297	596	128	46	14	3	44	4	18	5
14	1216	240	1226	288	590	134	47	9	—	33	5	15	2
15	1195	229	1202	259	585	140	48	8	1	28	5	13	3
16	1170	198	1185	223	573	116	49	6	—	21	2	10	2
17	1119	197	1149	210	558	122	50	6	—	18	2	7	—
18	1061	167	1116	189	547	106	51	3	—	15	2	7	1
19	1000	159	1078	177	522	91	52	1	—	12	1	5	3
20	930	134	1033	190	499	96	53	1	—	8	—	5	—
21	864	116	985	176	477	92	54	1	—	6	1	3	—
22	785	124	939	173	454	80	55	—	—	5	—	3	—
23	708	116	861	162	419	71	56	—	—	5	—	3	—
24	642	115	790	146	410	73	57	—	—	4	—	3	1
25	570	94	732	128	380	68	58	—	—	3	—	3	1
26	498	82	672	112	351	65	59	—	—	3	—	3	2
27	431	78	631	114	317	56	60	—	—	2	—	2	—
28	342	60	577	99	294	58	61	—	—	1	—	—	—
29	300	50	524	102	267	60	62	—	—	1	—	—	—
30	257	58	476	78	244	48	63	—	—	1	1	—	—
31	218	33	438	85	225	34	64	—	—	1	1	—	—
32	193	33	396	71	197	36	65	—	—	1	1	—	—
33	164	23	358	58	173	19	66	—	—	1	1	—	—

[1] There may be a secondary node at about the 29th to the 30th position. Possibly this is due to the fact that such positions are found only on the larger inflorescences.

TABLE X

NUMBERS OF FLOWERS, FRUITS AND SEEDS AT VARIOUS POSITIONS ON THE INFLORESCENCE IN 4 SERIES IN WHICH NUMBER OF SEEDS WAS DETERMINED

P	J. B. 1906			J. B. 1907			M. H. 1906			M. H. 1907		
	Fl.	Fr.	S.	Fl.	Fr.	S.	Fl.	Fr.	S.	Fl.	Fr.	S.
1	250	31	1062	250	39	1416	300	60	2585	300	58	2187
2	250	40	1269	250	49	1777	300	75	3032	300	56	2151
3	249	44	1715	250	58	2023	300	87	3660	300	55	2087
4	249	57	2130	250	70	2537	300	93	4044	300	77	3035
5	249	48	1605	250	71	2391	300	86	3483	300	75	2969
6	249	49	1801	250	73	2487	300	97	4251	300	90	3794
7	248	48	1376	250	68	2466	300	82	3569	300	94	3722
8	247	52	1687	250	85	2708	300	72	2876	299	82	3468
9	247	52	1639	250	85	3051	300	77	3444	298	79	3187
10	246	43	1501	250	63	2049	299	75	2991	297	72	2932
11	246	37	1121	249	70	2173	299	76	3263	297	68	3041
12	244	53	1717	249	60	1795	299	62	2733	296	72	2595
13	241	53	1460	249	45	1532	298	65	2566	296	59	2301
14	240	53	1332	247	49	1564	296	66	2886	292	61	2411
15	233	40	1121	242	42	1345	294	67	2937	292	66	2804
16	225	40	1254	240	47	1626	293	71	3064	286	56	2192
17	216	52	1182	234	30	1003	291	65	2532	279	56	2251
18	201	45	1389	223	34	1117	287	55	2590	273	55	1911
19	189	40	1172	211	37	1222	281	62	2691	263	49	1697
20	172	30	808	205	35	1099	273	60	2488	247	43	1558
21	157	22	779	194	28	727	263	40	1569	235	39	1363
22	132	29	925	188	26	728	249	49	1904	224	34	1180
23	114	22	576	174	24	848	239	50	2068	205	35	1276
24	102	23	841	156	22	528	232	45	1643	201	33	1037
25	94	19	573	142	17	482	220	38	1495	188	35	1482
26	80	17	477	127	18	508	207	55	2024	173	32	1093
27	71	13	327	116	14	414	192	32	1324	157	30	1136
28	60	7	259	102	14	384	174	30	1156	141	26	992
29	54	10	224	95	15	489	157	25	1018	127	24	739
30	47	5	114	90	11	332	146	24	920	114	21	760
31	41	6	234	83	17	542	133	34	1288	105	14	418
32	40	8	175	77	13	415	115	14	686	91	10	324
33	34	6	165	69	13	410	109	23	753	77	9	261
34	30	5	131	60	8	257	93	17	585	70	8	273
35	25	2	56	51	4	59	81	11	372	57	12	310
36	21	3	68	39	8	215	64	9	401	47	6	170
37	15	1	5	34	3	52	55	11	430	44	9	298
38	13	3	121	28	3	86	48	9	315	35	4	169
39	9	1	30	26	4	72	45	8	287	31	5	183
40	8	2	63	22	3	44	40	6	203	26	6	159
41	7	2	50	19	3	51	34	6	236	21	3	45
42	6	2	15	16	5	95	31	6	232	17	2	64
43	5	2	29	13	2	92	24	6	204	14	4	151
44	3	2	5	11	3	89	23	5	151	11	3	76
45	3	—	—	8	2	80	21	1	22	7	2	120
46	2	1	28	5	1	16	16	—	—	6	2	60
47	2	—	—	2	1	12	13	1	42	5	—	10
48	1	—	—	1	—	—	12	3	81	5	1	28
49	1	—	—	1	—	—	7	1	30	5	1	25
50	1	—	—	1	—	—	6	—	—	5	—	31
51	—	—	—	1	—	—	6	2	46	5	—	28
52	—	—	—	1	—	—	6	1	50	3	2	—
53	—	—	—	1	—	—	6	1	64	3	—	—
54	—	—	—	1	—	—	5	1	43	2	—	—
55	—	—	—	1	—	—	2	—	—	2	—	—
56	—	—	—	1	—	—	—	—	—	2	—	—
57	—	—	—	1	—	—	—	—	—	2	—	—
58	—	—	—	1	—	—	—	—	—	2	1	—
59	—	—	—	1	—	—	—	—	—	2	1	—
60	—	—	—	1	—	—	—	—	—	2	—	—

The investigation of this question has its obvious bearing on the problem of periodicity. Periodicity is the term used by de Vries and other biologists to express the idea that the form or size of the organs produced laterally along an axis is to some extent correlated with their position in such a manner that as one passes from the proximal to the distal region of the axis there is at first an increase to a maximum and then a decrease of the value of the character of the laterally produced organ.

TABLE XI

FREQUENCY DISTRIBUTION OF NUMBER OF SEEDS PER LOCULE IN 4 SERIES

Seeds per locule	J. B. 1906	J. B. 1907	M. H. 1906	M. H. 1907
?	—	14	—	10
0	307	212	104	129
1	117	96	51	80
2	139	138	91	86
3	172	162	145	130
4	153	173	153	157
5	153	161	189	200
6	164	206	224	207
7	143	225	245	249
8	143	215	278	224
9	173	218	287	253
10	143	214	293	264
11	161	213	280	280
12	124	243	329	315
13	133	219	291	302
14	151	214	300	278
15	128	218	311	255
16	134	159	348	278
17	110	183	292	242
18	105	175	286	219
19	93	111	291	197
20	82	96	218	194
21	77	85	199	106
22	66	77	198	130
23	40	42	169	109
24	40	27	136	82
25	35	34	84	60
26	28	13	79	54
27	15	16	59	36
28	10	9	32	37
29	8	5	27	14
30	6	1	28	12
31	4	—	12	8
32	—	2	11	5
33	1	—	2	4
34	2	—	3	1
35	—	—	3	—
36	—	—	1	2
37	—	—	—	1
38	—	—	2	1

The literature bearing on this problem is now fairly extensive, but little has been written concerning the possible relationship between the fertility characters of the fruit and its position on the inflorescence axis.

It should be evident that the differences in the proportion of fruits developing at different positions on the inflorescence present a series of problems of morphogenetic and physiological significance. Unfortunately the systematic collection of data for the solution of such problems has hardly been begun.

TABLE XII

FREQUENCY DISTRIBUTION OF NUMBER OF SEEDS PER FRUIT IN 4 SERIES

Seeds per capsule	II	VI	I	IV	Seeds	II	VI	I	IV	Seeds	II	VI	I	IV
?	—	13	—	8	36	22	24	31	32	73	3	4	6	8
0	47	44	1	17	37	18	29	28	30	74	3	1	8	8
1	8	3	—	3	38	18	34	38	34	75	5	—	9	5
2	16	1	—	1	39	20	34	41	40	76	1	2	5	6
3	15	5	2	1	40	16	18	40	35	77	1	2	4	2
4	16	9	2	3	41	19	24	35	41	78	2	3	12	3
5	16	11	2	11	42	18	19	34	26	79	1	1	9	6
6	13	9	7	8	43	9	23	39	31	80	3	—	8	5
7	16	12	8	7	44	16	21	37	33	81	2	2	8	1
8	16	16	13	15	45	13	29	36	33	82	—	—	2	1
9	20	19	15	11	46	17	19	44	38	83	1	—	4	3
10	15	20	16	15	47	11	31	36	39	84	1	—	1	3
11	15	16	10	18	48	16	30	31	27	85	3	1	3	4
12	20	24	14	15	49	16	26	38	33	86	1	—	2	2
13	19	22	25	21	50	14	23	38	23	87	—	—	3	—
14	20	13	16	12	51	17	22	36	24	88	—	—	—	2
15	21	28	20	15	52	12	15	36	22	89	—	—	—	—
16	28	12	31	22	53	8	15	29	23	90	—	—	1	—
17	28	21	17	25	54	13	12	31	26	91	—	—	1	—
18	14	30	23	17	55	17	10	34	22	92	—	1	1	1
19	27	29	25	31	56	12	14	36	21	93	—	—	3	—
20	26	32	31	30	57	8	13	42	20	94	—	—	1	1
21	19	16	34	33	58	10	12	30	24	95	—	—	—	—
22	15	29	50	35	59	6	7	34	12	96	—	—	1	—
23	13	24	29	34	60	13	5	19	15	97	1	—	—	1
24	16	26	31	26	61	13	10	28	21	98	—	—	—	—
25	24	22	24	31	62	6	13	25	17	99	—	—	2	—
26	18	34	33	26	63	7	10	30	22	100	—	—	—	—
27	13	32	45	37	64	3	8	24	14	101	—	—	—	—
28	31	31	29	34	65	5	8	16	15	102	—	—	1	—
29	17	29	43	38	66	5	9	21	8	103	—	—	—	—
30	17	23	38	28	67	5	5	21	17	104	—	—	—	—
31	15	33	45	35	68	6	5	12	12	105	—	—	—	—
32	11	19	30	28	69	2	5	11	11	106	—	—	—	—
33	14	22	40	40	70	6	2	13	11	107	—	—	—	1
34	12	28	37	34	71	4	2	15	9	108	—	—	—	—
35	14	31	37	43	72	6	1	10	5	109	—	—	—	—

Looking at the matter in a wholly superficial way, one is inclined to suggest, as a basis for the planning of further investigation, that the maturation of the more proximal ovaries is not favored by the conditions of the inflorescence which are most favorable for the development of the terminal portions where the floral parts are being matured for anthesis. The failure of the more distally placed ovaries to develop to maturity in such large numbers as those in the more central region of the inflorescence is possibly attributable to the demands for fruit- and seed-forming substances made by more proximal ovaries already in an advanced stage of development.

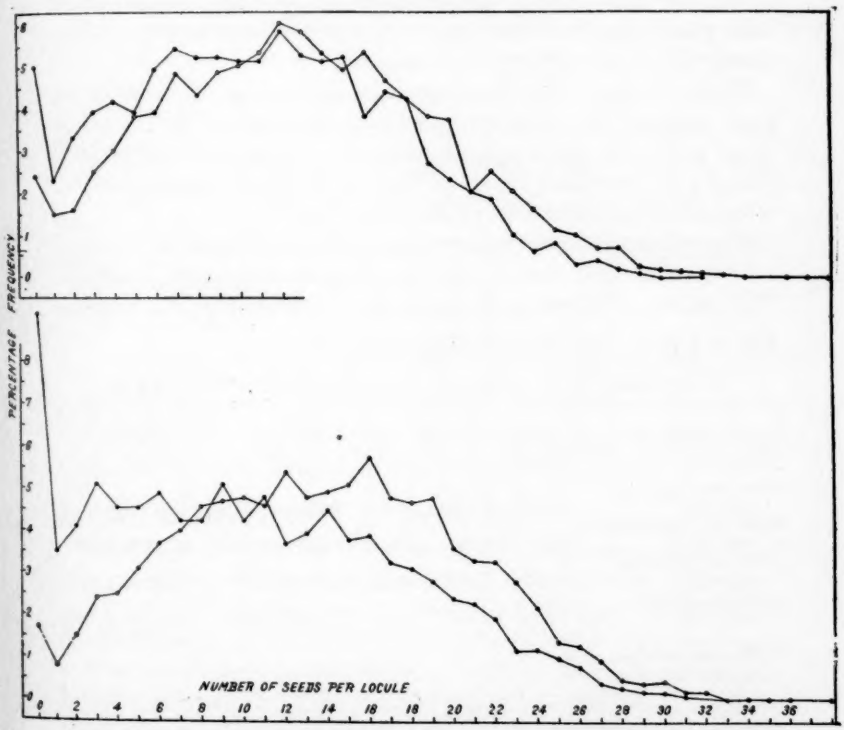

Fig. 6. Percentage frequency distribution of number of seeds per locule. Circles = Meramec Highlands, solid dots = Jefferson Barracks. Lower figure represents results for 1906, upper figure those for 1907.

The frequency distribution of number of seeds per locule in the 4 series is shown in table XI, while the distribution of number of seeds per capsule, comprising 3 locules, appears in table XII.

The distributions of seeds per locule, reduced to percentage frequencies, are represented graphically in fig. 6. These distributions require consideration from 2 sides: first, that of the differences between the series collected in different years in the same habitat, or in different habitats in the same year; second, that of their general nature as considered in comparison with biological frequency distribution in general. While neither of these questions can be fully considered independently of the other, the discussion of the difference in the material associated with year or habitat can be made in a preliminary way in simpler terms, and hence will be first taken up.

These 4 series have in common a wide range of variation in seed number, giving broad, relatively flat-topped distributions. In all series the distribution is bimodal. There is a conspicuous primary or secondary mode on 0 seeds per locule and another in the general region of 8 to 14 seeds per locule.

The agreement between the series from the habitats is in general very good in 1907, but in 1906 the 2 series differ conspicuously. That taken at Jefferson Barracks has a conspicuous mode on no

TABLE XIII

STATISTICAL CONSTANTS FOR NUMBER OF SEEDS PER LOCULE

Series	N	Mean	Standard deviation	Coefficient of variation
Meramec Highlands 1906 (I)	6051	13.7708±.0588	6.7898±.0416	49.3058±.3684
Meramec Highlands 1907 (IV)	5201	12.7963±.0623	6.6698±.0440	52.1229±.4280
Jefferson Barracks 1906 (II)	3360	10.3009±.0842	7.2394±.0595	70.2793±.8154
Jefferson Barracks 1907 (VI)	4162	10.9077±.0670	6.4086±.0473	58.7530±.5645
Differences between two years (1906—1907)				
Meramec Highlands	—	+0.9745±.0857	+0.1200±.0607	− 2.8171±.5647
Jefferson Barracks	—	−0.6068±.1076	+0.8308±.0760	+11.5263±.9917
Differences between two habitats (M. H.—J.B.)				
1906	—	+3.4699±.1027	−0.4496±.0726	−20.9735±.8948
1907	—	+1.8886±.0915	+0.2612±.0646	− 6.6301±.7084

seeds matured, and relatively high frequencies on the lower numbers of seeds per locule, whereas that taken at Meramec Highlands shows a relatively low mode on 0 seeds matured with a shift of the mode to a much higher seed number than in the Jefferson Barracks series.

To carry these comparisons somewhat further, and to prepare for more detailed consideration of the nature of these frequency distributions, we may consider the simpler statistical constants in table XIII for number of seeds per locule and in table XIV for

TABLE XIV

STATISTICAL CONSTANTS FOR NUMBER OF SEEDS PER FRUIT

Series	N	Mean	Standard deviation	Coefficient of variation
Meramec Highlands 1906 (I)	2017	41.3123±.2748	18.3094±.1944	44.3195± .5548
Meramec Highlands 1907 (IV)	1729	38.3829±.2947	18.1931±.2085	47.3991± .6539
Jefferson Barracks 1906 (II)	1120	30.9027±.4063	20.1417±.2872	65.1777±1.2631
Jefferson Barracks 1907 (VI)	1379	32.8426±.3165	17.4688±.2240	53.1893± .8545
Differences between two years (1906—1907)				
Meramec Highlands	—	+ 2.9294±.4029	+0.1163±.2851	− 3.0796± .8575
JeffersonBarracks	—	− 1.9399±.5150	+2.6729±.3642	+11.9884±1.5250
Differences between two habitats (M. H.—J. B.)				
1906	—	+10.4096±.4905	−1.8323±.3468	−20.8582±1.3796
1907	—	+ 5.5403±.4325	+0.7243±.3060	− 5.7902±1.0760

number of seeds per fruit. The differences between the constants for the 2 years in the same habitat and between the constants for the 2 habitats in the same year also appear in these tables.

The means and standard deviations will be used in calculating the coefficients of correlation set forth in the following paragraphs.

The conspicuous feature of the tables is the large size of the coefficients of variation. It is unnecessary in this place to bring together the many coefficients of variation for number of seeds per locule or per fruit which have been published in the literature, or to do more than to say that they are generally large.

Turning to the comparisons between the 2 years in the same habitat, we note that while the difference in means is perhaps statistically significant[1] in the 2 cases it is relatively small, being about 5 per cent in the 2 instances. It is also to be noted that in one habitat it is the 1906 series, whereas in the other it is the 1907 series, which has the higher seed production.

The differences between the 2 habitats in the same year show that for both years seed production is materially and significantly higher in the Meramec Highlands than in the Jefferson Barracks plants.

2. THE RELATIONSHIP BETWEEN THE NUMBER OF FLOWERS AND THE NUMBER OF CAPSULES MATURED

The relationship between number of flowers per inflorescence and the number of fruits per inflorescence may be computed for

TABLE XV

CORRELATION BETWEEN NUMBER OF FLOWERS AND FRUITS PER INFLORESCENCE

Series	N	Correlation between number of flowers and fruits	$\frac{r}{E_r}$	Correlation, flowers per inflorescence, and deviation of fruits from their probable value	$\frac{r}{E_r}$
Meramec Highlands 1906 (I)	300	.6751±.0212	31.84	.0278±.0389	0.71
Meramec Highlands 1907 (IV)	300	.6565±.0222	29.57	−.0986±.0386	2.55
Meramec Highlands 1907 (V)	305	.6047±.0245	24.68	.0451±.0385	1.17
Meramec Highlands 1907 (IV)+(V)	605	.6261±.0167	37.49	.0343±.0274	1.25
Jefferson Barracks 1906 (II)	250	.6125±.0267	22.94	.0576±.0425	1.36
Jefferson Barracks 1906 (III)	1000	.6416±.0125	51.33	.0693±.0212	3.27
Jefferson Barracks 1906 (II)+(III)	1250	.6374±.0113	56.41	.0771±.0190	4.06
Jefferson Barracks 1907 (VI)	250	.5344±.0304	17.58	−.1035±.0422	2.45
Jefferson Barracks 1907 (VII)	1020	.6897±.0111	62.14	.0652±.0210	3.10
Jefferson Barracks 1907 (VI)+(VII)	1270	.6638±.0106	62.62	.0407±.0189	2.15

the 4 series in which the seeds were counted from the entries in table I. For the 3 other series in which only the number of flowers and fruits were determined the reader must refer to table II.

The relationship between the number of flowers formed and the number of capsules matured per inflorescence is expressed in

[1] The ordinary formulae have been used in calculating the probable errors, although the correlation between the locules of the same fruit complicates somewhat their interpretation.

terms of correlations in the first correlation column of table XV. These coefficients are remarkably uniform from series to series. They range from 0.534 ± 0.030 to 0.690 ± 0.011. These *extremes* differ by only 0.156 ± 0.032. In general the series cannot be considered to differ significantly in correlation.

The relationship between the number of capsules matured and the number of flowers formed is expressed in terms of linear regression equations in table XVI.

TABLE XVI

STRAIGHT LINE EQUATIONS SHOWING THE RELATIONSHIP BETWEEN NUMBER OF FRUITS AND FLOWERS PER INFLORESCENCE

Series	Regression equation
Meramec Highlands 1906 (I)	$c = -.2113 + .2316f$
Meramec Highlands 1907 (IV)	$c = -.1139 + .2138f$
Meramec Highlands 1907 (V)	$c = -.3830 + .2280f$
Meramec Highlands 1907 (IV) + (V)	$c = -.2652 + .2216f$
Jefferson Barracks 1906 (II)	$c = -.3602 + .2062f$
Jefferson Barracks 1906 (III)	$c = -.5348 + .2382f$
Jefferson Barracks 1906 (II) + (III)	$c = -.5346 + .2335f$
Jefferson Barracks 1907 (VI)	$c = +.7869 + .1755f$
Jefferson Barracks 1907 (VII)	$c = -.4719 + .2491f$
Jefferson Barracks 1907 (VI) + (VII)	$c = -.3002 + .2376f$

The slopes of these lines range from + .1755 in the series of 250 inflorescences taken at Jefferson Barracks in 1907 to + .2491 in the large series taken at the same locality in the same year.

The fact that the widest disagreement is found in 2 series from the same habitat and year emphasizes the closeness of agreement between the results of the several series.

The equations for 2 of the series are represented graphically in fig. 7 for 1906, in which the empirical and theoretical means for 2 different habitats but for the same year, are laid side by side.

Two features of these diagrams will at once attract the eye: first, the excellent fit of the straight lines to the data; second, the remarkable closeness of agreement of the series from the 2 habitats.

While the correlation coefficients and the regression equations showing the relationship between the number of flowers and capsules per inflorescence have descriptive value, the physiological interrelationship between f and c may be best shown by a coefficient measuring the relationship between the number of flowers

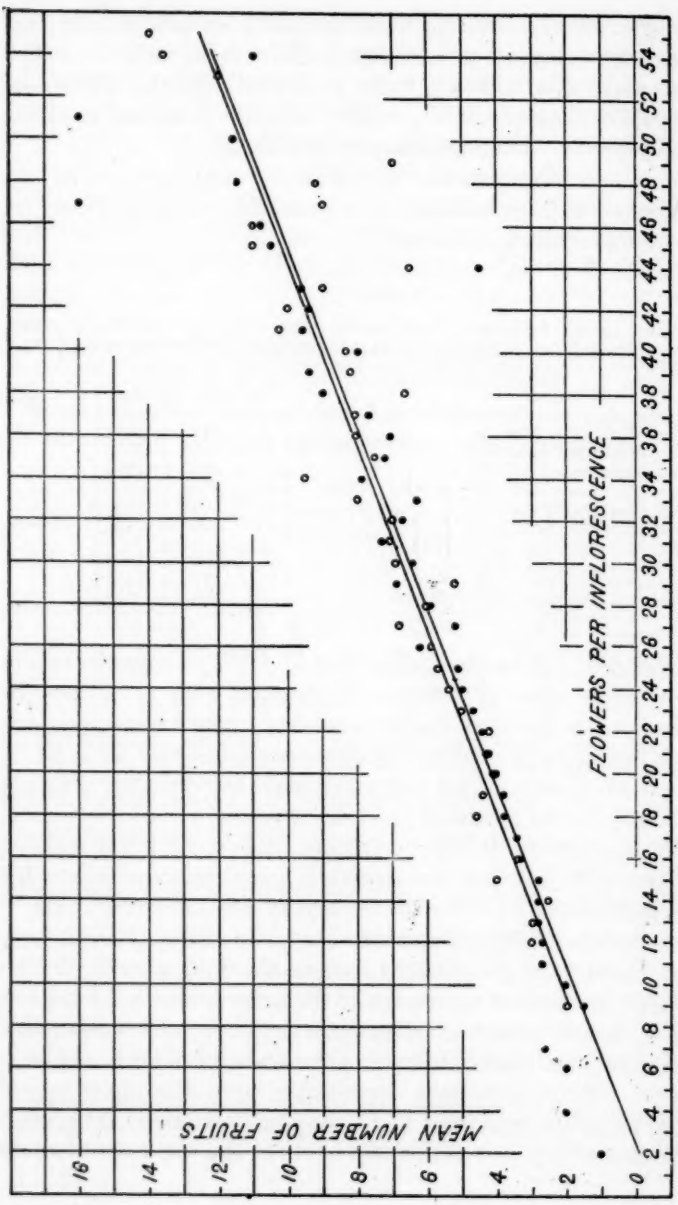

Fig. 7. Regression of number of fruits on number of flowers per inflorescence. Upper line = Meramec Highlands; lower line = Jefferson Barracks. Empirical means for Meramec Highlands represented by circles, those for Jefferson Barracks by solid dots.

and the deviation of the number of fruits from the number which would be expected if the number of capsules were proportional to the number of flowers formed throughout the entire range of variation of number of flowers per inflorescence.

The requisite formula has been given (Harris, '09a) and its range of applicability illustrated elsewhere (Harris, '18).

The results are given in the second correlation column of table xv. The values are low throughout. Eight are positive, while 2 are negative in sign. In general the coefficients are insignificant in comparison with their probable errors.

Taking these results as a whole, they indicate a slight relationship between the number of flowers per inflorescence and the capacity of the inflorescences for maturing their ovaries into fruits. Larger inflorescences mature on the average a slightly, but only slightly, larger proportion of their ovaries into fruits.

Turning to the literature for comparable cases, we note that in *Staphylea* (Harris, '09 a) and in *Crinum* (Harris, '12 a) inflorescences which produce larger numbers of flowers mature relatively smaller numbers of fruits. This is also the result announced by Reed for the lemon (Reed, '19). In *Celastrus* (Harris, '09) there is apparently no relationship between the number of flowers formed and the capacity of the inflorescence for maturing its ovaries into fruits.

3. THE RELATIONSHIP BETWEEN THE NUMBER OF FLOWERS PER INFLORESCENCE AND THE POSITION OF THE FRUITS

The foregoing analysis has shown that there is little relationship between the size of the inflorescence and the capacity for maturing its ovules into seeds.

We now have to consider another problem regarding fruit formation. This is: Has the size of the inflorescence as measured by the number of flowers which it produces an influence upon the position of the fruits which develop?

The problem of the relationship between the number of flowers and the position of the fruits which develop to maturity seems to be one of very real physiological interest. If we ignore for the moment the possible influence of the morphogenetic factor discussed above (p. 434) and look at the purely nutritional one, it

seems reasonable to assume that development of fruit makes a certain demand upon the organism for plastic materials. If this demand is higher than the available supply in any case, it seems quite possible that the more proximal ovaries, which are the first to have their seeds fertilized, would develop into fruits in larger proportions, since they are in a position to make the first demand upon the plastic materials.

If, on the other hand, the organism is so exactly coordinated that the quantities of plastic materials available for the formation of fruits and seeds is proportional to the number of flowers formed,[1] one might expect that the position of the fruits would be little influenced by the number of flowers per inflorescence.

To solve this problem we may proceed in the following manner. We may determine the relation between the number of flowers per inflorescence and the position of the fruits which develop to maturity. In doing this we weight the number of flowers per inflorescence with the number of fruits produced, and consider the position of each fruit on the axis a deviation from the standard (proximal) position.[2] We must expect this relation to be large, since it is evident that on the average the fruits on large inflorescences, which produce more fruits, will be inserted higher than those which produce few fruits. It is possible, however, to determine the true physiological relationship between these 2 characters by the use of the formula measuring the relation between a variable and the deviation of a dependent variable from its probable value cited above. The position of any fruit must always represent some fraction, or component, of the maximum possible position on the inflorescence to which it belongs. This formula, therefore, seems quite applicable.

The correlation between the number of flowers per inflorescence and the position of the fruits on the inflorescence, and between the number of flowers on the inflorescence and the deviation of the position of the fruits from its probable position appear in table XVII.

[1] One may, if he chooses, look upon the number of flowers formed as very closely proportional to the quantities of plastic substances which are to be available for maturing these ovaries into fruit.

[2] The full data for the determination of these constants are rather too voluminous for publication here.

TABLE XVII

CORRELATION BETWEEN POSITION OF FRUITS ON THE INFLORESCENCE AND NUMBER OF FLOWERS PER INFLORESCENCE

Series	Weighted N	Correlation between number of flowers and position of fruits	$\frac{r}{E_r}$	Correlation, flowers per inflorescence and deviation of position of fruits from its probable position	$\frac{r}{E_r}$
Meramec Highlands 1906 (I)	2017	.4151±.0322	12.89	.0162±.0389	0.42
Meramec Highlands 1907 (IV)	1737	.4605±.0307	15.00	.0314±.0389	0.81
Meramec Highlands 1907 (V)	1849	.4794±.0297	16.14	.0216±.0386	0.56
Meramec Highlands 1907 (IV)+(V)	3586	.4726±.0213	22.18	.0291±.0274	1.06
Jefferson Barracks 1906 (II)	1120	.4843±.0327	14.81	−.0332±.0426	0.78
Jefferson Barracks 1906 (III)	5361	.4266±.0174	24.51	.0280±.0213	1.31
Jefferson Barracks 1906 (II)+(III)	6481	.4328±.0155	27.92	.0151±.0191	0.79
Jefferson Barracks 1907 (VI)	1392	.4677±.0333	14.04	.0536±.0425	1.26
Jefferson Barracks 1907 (VII)	6534	.4344±.0171	25.40	−.0151±.0211	0.72
Jefferson Barracks 1907 (VI)+(VII)	7926	.4399±.0153	28.75	−.0057±.0191	0.30

If there be no relationship between the number of flowers per inflorescence and the position of the fruits on the inflorescence, one should find a linear relationship between the average position of the fruits and the number of flowers per inflorescence. The equations to the straight lines in 4 of the series are:

Meramec Highlands, 1906, 300 inflorescences, 2017 fruits

$$p = -.554747 + .482806\,f$$

Jefferson Barracks, 1906, 1250 inflorescences, 6481 fruits

$$p = -.400325 + .472802\,f$$

Meramec Highlands, 1907, 605 inflorescences, 3586 fruits

$$p = -.857833 + .512934\,f$$

Jefferson Barracks, 1907, 1270 inflorescences, 7926 fruits

$$p = +.160829 + .447496\,f$$

The lines and empirical means for the 1906 series appear in fig. 8. The results indicate sensible linearity.

Turning to the problem of the correlation between number of flowers per inflorescence and deviation of position of fruits from its probable value, we note that the values are low throughout. They are generally smaller than their probable errors. Thus they indicate that the number of flowers per inflorescence has practically no influence on the position of the fruits which develop to maturity.

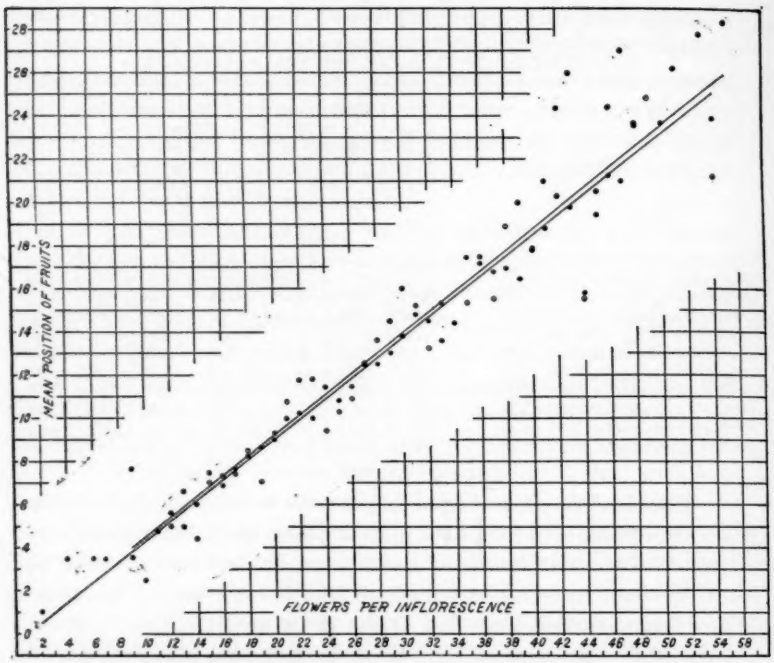

Fig. 8. Regression of position of fruits on number of flowers per inflorescence in 2 habitats for 1906. Upper line and circles = Meramec Highlands, lower line and solid dots = Jefferson Barracks.

In so far as they are pertinent to the problem, the constants in this table seem to show that the supply of fruit- and seed-forming substance is very nearly proportional to the number of flowers formed. These results are in full agreement with those of the preceding section (2) in which it was shown that there is little relationship between the number of flowers on the inflorescence and the capacity of the inflorescence for maturing these flowers into fruit.

4. THE RELATIONSHIP BETWEEN THE NUMBER OF FLOWERS AND FRUITS PER INFLORESCENCE AND THE NUMBER OF SEEDS PER LOCULE

We have, in this section, to consider the problem of the possible relationships between the size of the inflorescence as measured by

the number of flowers and fruits which it produces and the fertility of its fruits.

This seems a question of very real physiological interest On *a priori* grounds one might be inclined to suggest that the size of the inflorescence is a measure of vigor, and that, as another expression of the greater vigor, larger numbers of seeds would be expected to be associated with larger numbers of flowers per inflorescence. On the other hand, it may be urged that since the inflorescences with larger numbers of flowers also produce larger numbers of fruits, the demands for plastic materials due to greater numbers of fruits would result in a reduction rather than in an increase in the number of seeds per locule.

The product moments for the relationship between the number of flowers per inflorescence and numbers of seeds per fruit may be calculated from table I.[1]

Table XVIII shows the correlation between the number of flowers per inflorescence and the number of seeds per locule and between the number of fruits per inflorescence and the number of seeds per locule in the 4 series in which the numbers of seeds were determined.

Three of the constants measuring the relationship between the number of flowers and the number of seeds are positive, while one is negative in sign. All are small, however, ranging from -0.020 to $+0.095$. In general the coefficients are not as large as their probable errors.[2]

Correlations between the number of fruits per inflorescence and

[1] Note that in determining the relationship between number of flowers and number of seeds the means and standard deviations for number of flowers per inflorescence must be redetermined by weighting with the number of fruits or number of locules per inflorescence. The constants thus weighted may be used in the determination of correlations for number of flowers and number of seeds per locule or seeds per fruit, since all of the fruits are trilocular.

[2] The question of the number to be used in calculating the probable error of these constants has presented considerable difficulty. The number of fruits in which the seeds were counted has been very large. If this N were used in the determination of the probable error it would be very small indeed. It may be questioned, however, whether the probable error of the correlation between a weighted variable x and another variable y is any lower than that obtained when the unweighted number of the x characters is used. We have, therefore, in determining these probable errors taken N to be the actual number of inflorescences.

the number of seeds per locule may be deduced from the condensed correlation table appearing as table IV.[1]

The correlations between the number of fruits and the number of seeds per locule as given in table XVIII are negative in all 4 of the cases but are of a very low order, ranging from -0.043 to -0.127. Two of the 4 are over twice as large as their probable errors.

TABLE XVIII

CORRELATION BETWEEN FLOWERS PER INFLORESCENCE AND NUMBER OF SEEDS PER LOCULE AND BETWEEN NUMBER OF FRUITS PER INFLORESCENCE AND NUMBER OF SEEDS PER LOCULE

Series	Flowers and seeds	$\frac{r}{E_r}$	Fruits and seeds	$\frac{r}{E_r}$	Difference	$\frac{\text{Diff.}}{E_{\text{diff.}}}$
Meramec Highlands 1906	$+.0321\pm.0389$	0.825	$-.0429\pm.0389$	1.102	$-.0750\pm.0387$	1.938
Meramec Highlands 1907	$+.0382\pm.0388$	0.985	$-.0569\pm.0388$	1.466	$-.0951\pm.0387$	2.457
Difference	$+.0061\pm.0548$	0.111	$-.0140\pm.0548$	0.255	———	—
Jefferson Barracks 1906	$+.0952\pm.0423$	2.250	$-.0867\pm.0423$	2.050	$-.1819\pm.0424$	4.290
Jefferson Barracks 1907	$-.0202\pm.0426$	0.474	$-.1265\pm.0420$	3.012	$-.1063\pm.0600$	1.772
Difference	$-.1154\pm.0600$	1.923	$-.0398\pm.0600$	0.663	———	—

These results show that unless there are statistical considerations which invalidate the coefficients of correlation as measures of interdependence in these cases, the relationship between the characteristics of the inflorescence and the number of seeds matured is very slight indeed. Apparently inflorescences which are initially large tend to have capsules with slightly larger numbers of seeds. Inflorescences which mature a large number of capsules tend to have a slightly smaller number of seeds in these capsules. The difference between the correlations for number of fruits and seeds and the number of flowers and seeds shows that in all 4

[1] The frequencies used in calculating the correlations given in this paper are slightly different from those shown here because of the fact that 10 locules in series IV and 14 locules in series VI had a questionable number of seeds. The difference in results obtained from calculations from this table and those actually used in obtaining our constants can hardly be significant, since they depend merely on differences due to 10 out of 5211 and 14 out of 4176 locules.

collections the relation between number of fruits and seeds is more strongly negative than that between number of flowers and seeds. At least 2 of these differences may be significant in comparison with their probable errors.

The correlation coefficients in these tables show that the relationship between the number of flowers per inflorescence and the number of seeds per locule and between the number of fruits per inflorescence and the number of seeds per locule is very slight indeed. How slender it is may be best shown by the use of straight-line equations. In these the variable term shows the actual increase or decrease in number of seeds per locule associated with an increase in the number of flowers per inflorescence or in the number of fruits per inflorescence. The equations are:

Meramec Highlands, 1906,
$s = 12.9611 + .0250\,f$, $s = 14.5414 - .0965\,c$
Meramec Highlands, 1907,
$s = 11.9176 + .0291\,f$, $s = 13.7444 - .1335\,c$
Jefferson Barracks, 1906,
$s = 8.1589 + .0822\,f$, $s = 11.5831 - .2173\,c$
Jefferson Barracks, 1907,
$s = 11.3520 - .0151\,f$, $s = 12.6892 - .2585\,c$

where s = seeds, f = flowers, and c = fruits per inflorescence.

The lines and the empirical means are represented graphically for the relationship between number of flowers per inflorescence and number of seeds per locule in fig. 9, and for that between number of fruits per inflorescence and number of seeds per locule in fig. 10.

The mean numbers of seeds per locule are distributed with considerable irregularity about the nearly horizontal lines showing the theoretical change in mean number of seeds with variation in the number of flowers per inflorescence. There is, however, nothing in these lines to indicate that any single curve of a higher order would give a better representation of the relationship.

The lines and empirical means for number of seeds per locule of fruits produced on inflorescences with varying total numbers of fruits (fig. 10) may indicate a slightly non-linear distribution of

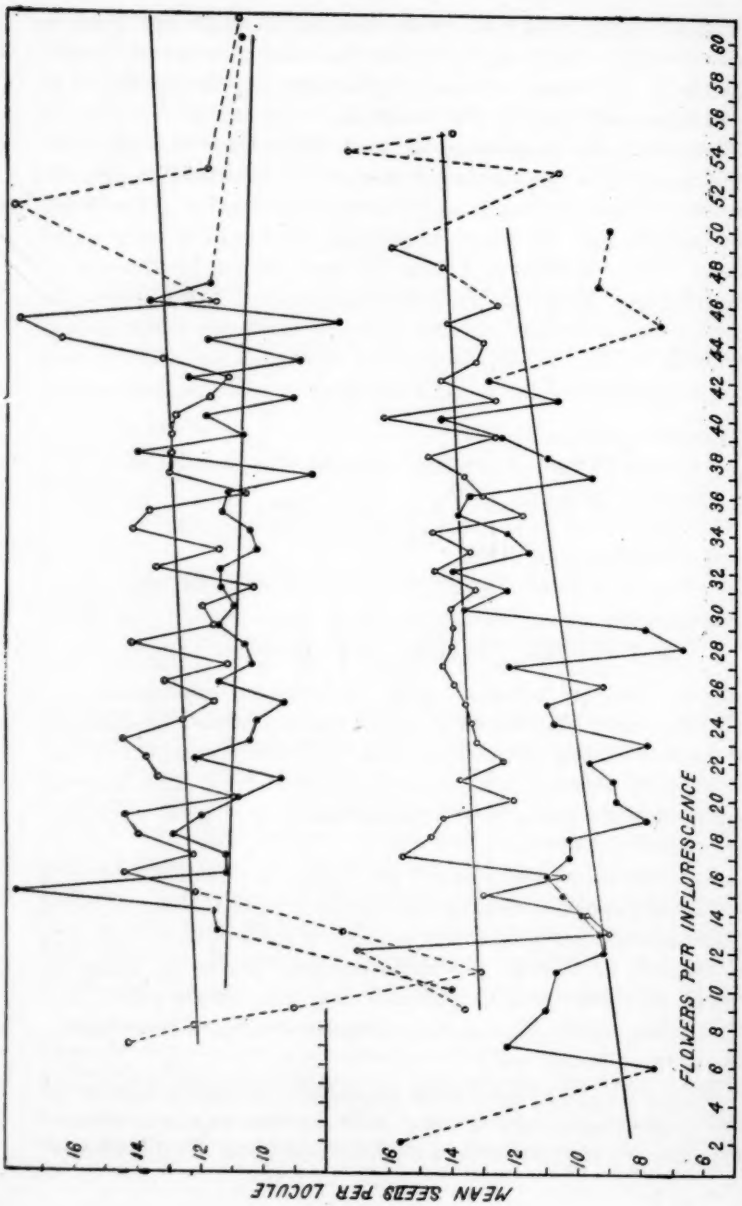

Fig. 9. Regression of number of seeds per locule on number of flowers per inflorescence. Circles represent empirical means for Meramec Highlands, solid dots those for Jefferson Barracks. Lower figure gives results for 1906, upper figure those for 1907.

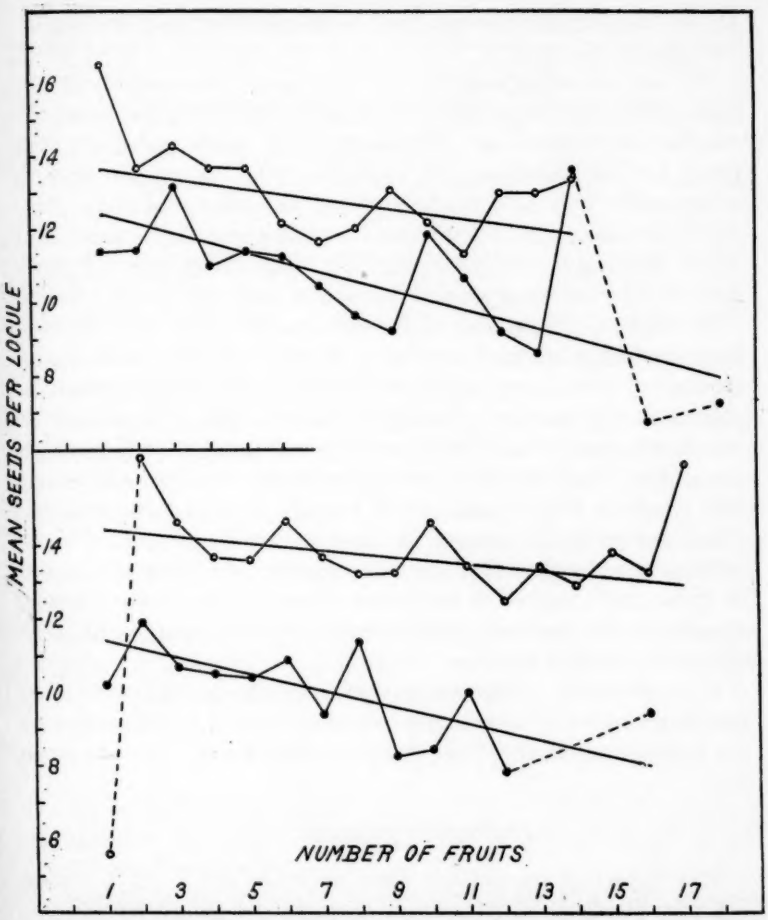

Fig. 10. Regression of number of seeds per locule on number of fruits per inflorescence. Circles represent empirical means for Meramec Highlands, solid dots those for Jefferson Barracks. Lower figure represents results for 1906, upper figure those for 1907.

the means.[1] They show, however, that there is a sensible decrease

[1] Further mathematical tests for non-linearity seem unadvisable because of the difficulties arising from the small frequencies in some of the classes, and because of the fact that the relationship between fruit and seed number is complicated by the relationship between flower and fruit number and flower and seed number, as shown in the following paragraphs.

in the number of seeds per fruit as the number of fruits per inflorescence increases.

We may therefore conclude that the correlation coefficient furnishes as adequate a measure of the relationship between the number of flowers per inflorescence and seeds per fruit, and fruits per inflorescence and seeds per fruit, as we are able to command. This measure shows that the relationship is, practically speaking, zero for the number of flowers and the number of seeds, but has a significant negative value for number of fruits matured per inflorescence and number of seeds ripened per locule.

It will be quite evident on mature consideration that the very low correlation between number of flowers per inflorescence and number of seeds may be the resultant of physiological relationships between number of capsules and number of seeds on the one hand, and the number of capsules and number of flowers, on the other. Inflorescences producing larger numbers of flowers also produce larger numbers of fruits. As a resultant of the positive correlation between number of flowers and capsules per inflorescence, r_{fc}, and of the negative correlation between number of fruits and number of seeds per locule, r_{cs}, one might expect the correlation between number of flowers and number of seeds to be sensibly lowered.[1]

It is necessary, therefore, to determine the partial correlation between number of flowers per inflorescence and number of seeds for constant number of capsules per inflorescence. This is given by

$$_{c}r_{fs} = \frac{r_{fs} - r_{fc}r_{cs}}{\sqrt{1 - r_{fc}^2}\sqrt{1 - r_{cs}^2}}$$

The values of $_{c}r_{fs}$ are set forth in table XIX. All 4 values are now positive. Furthermore they are (as shown by the difference column, $_{c}r_{fs} - r_{fs}$) larger than the uncorrected correlations.

Thus they indicate that if correction be made for the influence of the number of fruits whch mature, the inflorescences which are

[1] In inflorescences with larger numbers of fruits the plastic materials must be more extensively divided than in those with a small number of fruits. Number of fruits per inflorescence might, therefore, seem a more logical proximate cause of variation in the number of seeds matured than would number of flowers per inflorescence.

TABLE XIX

PARTIAL CORRELATION BETWEEN FLOWERS PER INFLORESCENCE AND SEEDS PER LOCULE FOR CONSTANT NUMBER OF FRUITS AND BETWEEN FRUITS AND SEEDS PER LOCULE FOR CONSTANT NUMBER OF FLOWERS PER INFLORESCENCE AND COMPARISON OF THE PARTIAL CORRELATIONS WITH THE GROSS CORRELATIONS

Series	Partial correlation, flowers and seeds $_{c}r_{fs}$	$_{c}r_{fs}-r_{fs}$	Partial correlation, fruits and seeds $_{f}r_{cs}$	$_{f}r_{cs}-r_{cs}$
Meramec Highlands 1906 (I)	+.0829±.0387	+.0508	−.0875±.0836	−.0446
MeramecHighlands1907(IV)	+.1003±.0385	+.0621	−.1088±.0385	−.0519
Jefferson Barracks 1906 (II)	+.1885±.0411	+.0932	−.1844±.0412	−.0977
Jefferson Barracks 1907(VI)	+.0565±.0425	+.0767	−.1370±.0419	−.0105

larger, as measured by the number of flowers which they produce, ripen slightly larger numbers of seeds per locule.

The reader will have noted that if the physiological relationship between size of inflorescence and number of seeds per locule be of a positive kind, such that (other factors being eliminated) larger inflorescences tend to mature larger numbers of seeds in their locules, this will tend to screen the true physiological relationship between the number of fruits matured per inflorescence and the number of seeds ripened per locule.

We therefore require the partial correlation between the number of capsules and number of seeds for constant number of flowers per inflorescence. The required formula is:

$$_{f}r_{cs} = \frac{r_{cs} - r_{fc}r_{fs}}{\sqrt{1 - r_{fc}^2}\sqrt{1 - r_{fs}^2}}$$

The coefficients are given in table XIX. These are negative throughout, and all have a higher negative value than that of the uncorrected correlation.

Turning to the literature for comparable observations, we note that while data for size of inflorescence and number of seeds per fruit cannot be obtained in *Cercis*, we do have a series of ovaries (Harris, '12) in which the number of ovules was counted under the microscope. The correlations between the number of flowers per inflorescence and the number of ovules per ovary have been shown to be: For tree 1, $r = -.007 \pm .023$; for tree 2, $r = +.030 \pm .021$; for tree 3, $r = +.134 \pm .024$. These constants are so low that their significance is questionable.

In *Celastrus* (Harris, '09) the correlation between both number of flowers and number of fruits per inflorescence, on the one hand, and number of seeds per fruit, on the other, are very low. The actual constants are:

For number of flowers and number of seeds, $r = + .033 \pm .013$.

For number of fruits and number of seeds, $r = - .012 \pm .013$.

The inflorescence and fruit of *Staphylea* has been rather exhaustively studied. It has been shown (Harris, '12b) that the average values of the correlation coefficients for a series of 20 shrubs studied at the Missouri Botanical Garden in 1906 are:

For fruits per inflorescence and ovules per locule,

$$r = .0192 \pm .0185.$$

For fruits per inflorescence and seeds per locule,

$$r = - .0399 \pm .0080.$$

For general samples of fruits, comprising the collections from all the shrubs, the correlations have been shown to be:

Year of collection	Number of locules	Fruits and ovules, r_{fo}	Fruits and seeds, r_{fs}
1906	6177	$+.0391 \pm .0086$	$-.0474 \pm .0086$
1908	12099	$+.0633 \pm .0061$	$-.0494 \pm .0061$
1909	6246	$-.0539 \pm .0085$	$+.0626 \pm .0085$

Two of the coefficients are negative. The correlation between the number of fruits per inflorescence and length of fruit in *Staphylea* has been found (Harris, '12) to be of the order $r = - .1828 \pm .0144$.

For *Crinum longifolium* (Harris, '12 a) the correlation between the number of fruits per inflorescence and number of seeds per fruit is $r = - .072 \pm .024$.

5. THE RELATIONSHIP BETWEEN THE ACTUAL AND THE RELATIVE POSITION OF THE FRUIT ON THE INFLORESCENCE AND THE NUMBER OF SEEDS PRODUCED

The proportion of the ovaries which develop into fruits at different positions on the inflorescence axis has already been discussed (p. 425).

In considering the influence of position on the inflorescence upon the development of the fruit, the only measure of position which requires consideration is that furnished by the position of the

flower. When we turn to the problem of the influence of position upon the development of the seed, it is clear that either the position of the flower on the axis or the position of the matured fruits in the series of fruits may be taken as a measure of position. Position in the latter case may be either the actual position which the matured ovary occupies in the series of flowers on the inflorescence or it may be the position which a fruit occupies in the series of fruits matured. For example, if the third flower from the proximal end of the inflorescence develops into a fruit it will be recorded as occupying the third position in the series of flowers. But if the first 2 flowers fail to develop it will occupy the first position in the series of fruits.

The first of these may be designated as the actual position of the fruit, the second as the relative position of the fruit.[1]

The total number of flowers, the total number of fruits, and the total number of seeds produced at each (actual) position on the inflorescence are shown for the 4 series of materials in which the number of seeds was determined in table x. From this table the correlations between actual position and number of seeds per locule, set forth in table xx, have been deduced.

The correlation between the relative position of the fruit and number of seeds per locule or per fruit may be deduced from the condensed correlation table xxi, in which the position of the fruit, the number of locules, and total number of seeds produced by those locules are shown for the 4 series of material in which number of seeds was determined.[2]

The relationship between the actual position of the fruit and the number of seeds matured per locule and that between the relative position of the fruit and the number of seeds matured per locule are laid side by side in table xx. These coefficients are, without exception, negative in sign. Thus the number of seeds

[1] Since in correlations between position on the inflorescence and number of seeds per locule or per fruit the position must be weighted with the number of fruits counted, the weighted constants are necessary. These may be deduced from the tables of data, but, since they are needed only for the correlations, are not tabled here.

[2] The correlation between the relative position and total seeds per fruit may be determined from this table by substituting the number of fruits for the number of locules and the means and the standard deviations of number of seeds per fruit for number of seeds per locule.

TABLE XX

CORRELATION BETWEEN THE ACTUAL POSITION OF THE FRUIT AND NUMBER OF SEEDS PER LOCULE AND BETWEEN THE RELATIVE POSITION OF THE FRUIT AND NUMBER OF SEEDS PER LOCULE

Series	Actual position and seeds	$\frac{r}{E_r}$	Relative position and seeds	$\frac{r}{E_r}$	Difference	$\frac{\text{Diff.}}{E_{\text{diff.}}}$
Meramec Highlands 1906 . .	−.0778±.0387	2.010	−.0541±.0388	1.394	+.0237±.0548	0.432
Meramec Highlands 1907 . .	−.1129±.0384	2.940	−.0500±.0388	1.288	+.0629±.0539	1.167
Difference. . .	−.0351±.0539	0.651	+.0041±.0548	0.075	———	—
Jefferson Barracks 1906	−.1147±.0420	2.730	−.1232±.0420	2.933	−.0085±.0592	0.143
Jefferson Barracks 1907	−.1229±.0420	2.926	−.1040±.0421	2.470	+.0189±.0592	0.319
Difference . .	−.0082±.0592	0.139	+.0192±.0592	0.324	———	—

TABLE XXI

NUMBER OF LOCULES AND TOTAL SEEDS AT VARIOUS RELATIVE POSITIONS ON THE INFLORESCENCE IN 4 SERIES IN WHICH NUMBER OF SEEDS WAS DETERMINED

Relative position	J. B. 1906		J. B. 1907		M. H. 1906		M. H. 1907	
	Locules	Total seeds	Locules	Total seeds	Locules	Total seeds	Locules	Total seeds
1	744	8267	747	8313	897	12278	891	11134
2	702	7671	731	8673	894	12641	869	11973
3	600	6153	687	7659	864	12553	833	11055
4	435	4568	582	6462	795	11051	711	9374
5	297	2757	453	5068	687	9392	558	6753
6	204	1948	326	3243	552	7527	448	5391
7	141	1395	222	2182	411	5577	318	3711
8	96	816	138	1243	333	4400	219	2836
9	60	551	96	953	231	2982	144	1767
10	42	239	66	612	153	1934	84	980
11	18	146	45	348	108	1437	57	722
12	9	71	27	251	63	789	45	551
13	3	11	15	103	30	393	18	248
14	3	1	9	111	15	142	6	59
15	3	16	6	16	9	150	—	—
16	3	1	6	109	6	68	—	—
17	—	—	3	37	3	13	—	—
18	—	—	3	15	—	—	—	—

matured in the more distal position is smaller than that in the more proximal position. The differences between the correlations for the same habitat for the 2 years cannot be considered significant in comparison with their probable errors. The corre-

lations are, however, of a very low order. Those for actual position and the number of seeds range from — 0.078 to — 0.123. Those for relative position and number of seeds range from — 0.050 to — 0.123. A comparison of the correlations between

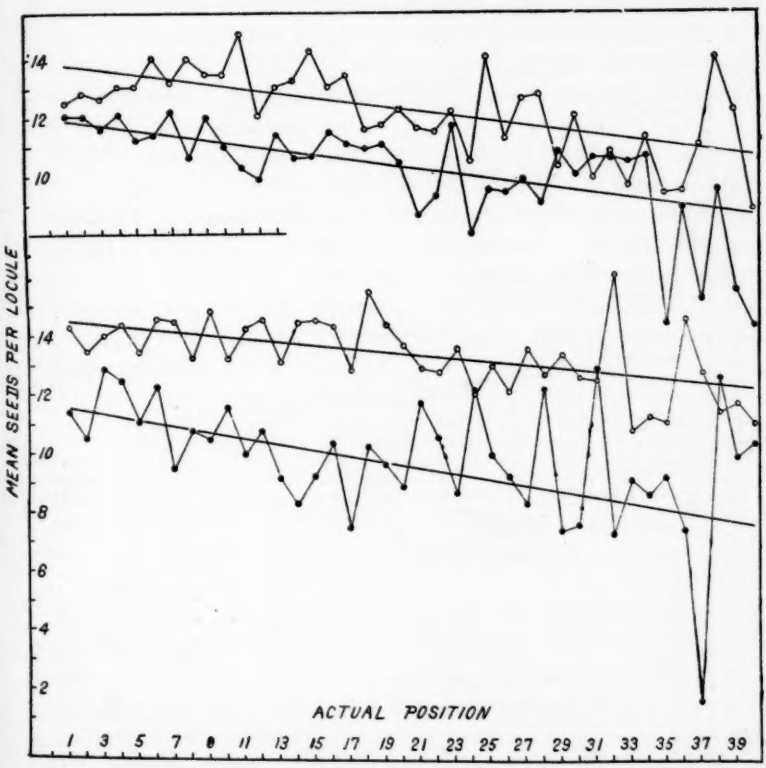

Fig. 11. Regression of number of seeds per locule on actual position of the fruit. Circles = Meramec Highlands, solid dots = Jefferson Barracks. The lower figure gives the results for 1906, the upper figure those for 1907.

the relative position and number of seeds, and actual position and number of seeds shows that in one case the former and in 3 cases the latter is the larger. No one of these differences is significant in comparison with the probable error of the determination. Thus it is impossible to assert on the basis of the materials now

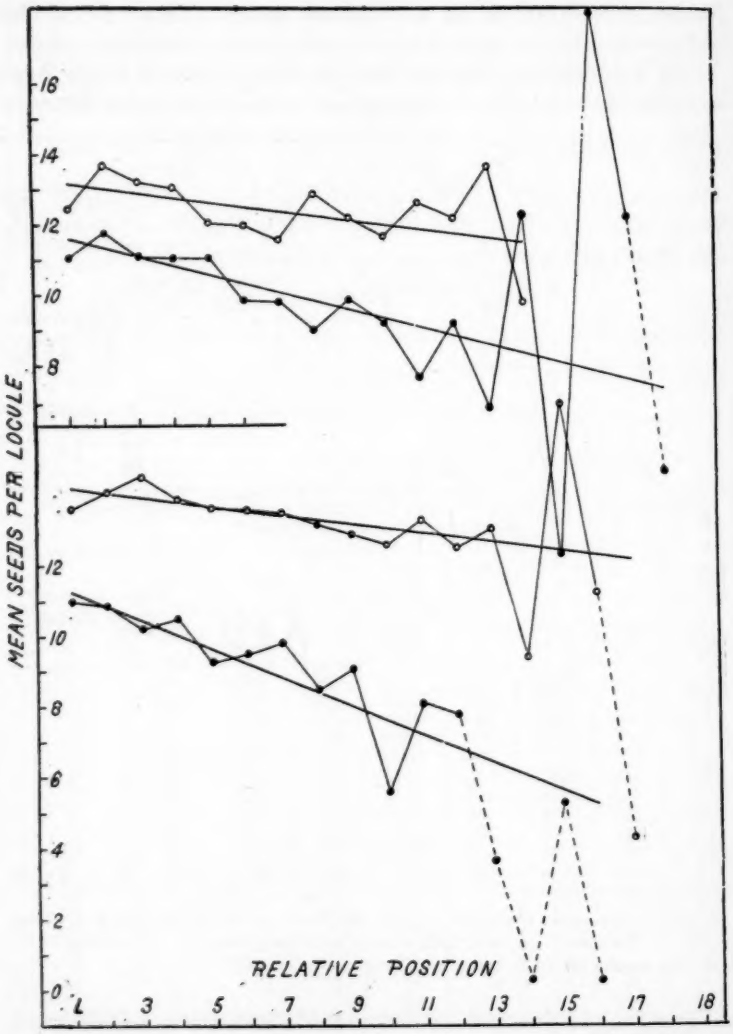

Fig. 12. Regression of number of seeds per locule on relative position of the fruit. Circles = empirical means for Meramec Highlands, solid dots = empirical means for Jefferson Barracks. Lower figure gives results for 1906, upper figure for 1907.

available that one of these relationships is more intimate than the other.

The low correlations between the actual position and the relative position of the fruit and the number of seeds which it produces may be due either to an absence of relationship between these two characters or it may be due to a periodicity in the inflorescence, such that the number of seeds at first increases and then decreases as one passes from the proximal toward the distal end of the inflorescence.

To test this matter we determine the mean number of seeds in each position, both actual and relative, on the inflorescence, and ascertain whether the change in mean number of seeds occurs at a uniform rate from the lower to the higher regions of the inflorescence. To be strictly valid the correlation coefficients should represent cases of linear regression. The linear equations showing the change in the number of seeds per locule with position on the inflorescence are as follows:

	Actual position	Relative position
Meramec Highlands, 1906	$s = 14.5551 - .0519\,a$	$s = 14.3458 - .1280\,r$
Meramec Highlands, 1907	$s = 13.9185 - .0787\,a$	$s = 13.3141 - .1279\,r$
Jefferson Barracks, 1906	$s = 11.6245 - .0980\,a$	$s = 11.6010 - .3769\,r$
Jefferson Barracks, 1907	$s = 12.0439 - .0850\,a$	$s = 11.8913 - .2491\,r$

Here a = actual position, r = relative position, and s = number of seeds per locule.

The lines for actual position are represented in fig. 11, while those for relative position appear in fig. 12. For both relationships and in all series of material these indicate a uniform decrease in number of seeds per inflorescence when the capsules are considered in series ranging from the proximal to the distal regions of the inflorescence.

For comparison we have a number of determinations on the inflorescence of *Staphylea*, in which the relationship between position and number of ovules (Harris, '11 a) and between position and number of seeds (Harris, '12 b) have been shown to be very small numerically but generally negative in sign. The relationship between position on the inflorescence and length of pod in *Staphylea* has also been shown (Harris, '12) to be slightly negative.

6. THE RELATIONSHIP BETWEEN THE NUMBER OF SEEDS IN THE LOCULES OF THE SAME FRUIT

The correlations between the number of flowers and fruits per inflorescence and the actual and relative position of the fruit on the inflorescence, on the one hand, and the number of seeds per locule, on the other, have been shown to be of a very low order indeed. We cannot, therefore, regard any of these earlier established characters, or the factors which determine them, as having a large influence in determining the number of seeds per locule.

Having failed to locate factors of material importance in the characters of the inflorescence, we may inquire whether there are unmeasurable factors which influence all of the locules of the same fruit in a similar manner.

This may be done by determining the inter-locular relationship for number of seeds per locule in the different series. In doing this, symmetrical tables are formed. The number of seeds in each locule is considered a first and then a second member of the pair in combination with the other locules of the fruit. The values of the correlation coefficients were checked by the use of the intra-class correlation formulae (Harris, '13).

The tables of data are too voluminous for publication.

The correlation coefficients and the regression equations are set forth in table XXII and show a high degree of similarity between numbers of seeds in the locules of the same fruit. The correlation lies between 0.70 and 0.80. Since the tables are symmetrical, the correlation and the regression coefficients are identical. The straight lines and the empirical means for the materials for the 2 pairs of years are shown in fig. 13. Apparently the straight line represents the relationship between the observed and the theoretical average as well as would any curve of higher order. The closely contiguous position of the lines for the years shows the generality of the laws underlying the interdependence between seed number in the 3 locules of the fruit.

Comparable determinations for other species are few in number. In *Sanguinaria* (Harris, '10) the correlations for number of ovules on the 2 placentae have been shown to be of the order $r = .89$ to $r = .92$, while the correlations for number of seeds per locule

TABLE XXII

CORRELATION BETWEEN NUMBER OF SEEDS PER LOCULE IN THE SAME FRUIT AND REGRESSION EQUATIONS SHOWING THE RELATION BETWEEN THE NUMBER OF SEEDS IN THE LOCULE OF THE FRUIT

Series	Weighted N	Correlation	Regression equation
Jefferson Barracks 1906	6720	.7901 ± .0044	$l_2 = 2.1619 + .7901\, l_1$
Meramec Highlands 1906	12102	.7119 ± .0043	$l_2 = 3.9669 + .7119\, l_1$
Jefferson Barracks 1907	8274	.7408 ± .0047	$l_2 = 2.8374 + .7408\, l_1$
Meramec Highlands 1907	10374	.7383 ± .0042	$l_2 = 3.3479 + .7383\, l_1$

have a value of $r = .80$ to $r = .84$. That the correlation for seed production is not due solely to the high correlation of the numbers of ovules on the 2 placentae is shown by the fact that the partial correlations between the numbers of seeds on the 2 placentae for constant numbers of ovules have a material value.

In *Hibiscus* (Harris, '13) it has been shown that for 1000 fruits examined at the Missouri Botanical Garden in the fall of 1905 the intra-ovarial correlations were

For ovules per locule, $r = .3843 \pm .0081$
For seeds per locule, $r = .5557 \pm .0066$

Excess for seeds $.1714 \pm .0104$

Here again the results indicate distinct physiological factors influencing the capacities of the several locules of the fruit for seed production in such a way as to bring about a similarity between them.

In *Crinum longifolium* a correlation of $r = .676 \pm .008$ has been demonstrated (Harris, '12 a) between the weight of the seeds from the same fruit.

All these results agree in indicating that there are morphogenetic or physiological factors tending to bring about a similarity in the seed production and in the seed weight of the locules of the fruit.

IV. Recapitulation and Discussion

This paper has had for its purpose the consideration of various problems of fertility in *Manfreda virginica* (*Agave virginica*). The conclusions are based on the statistical analysis of extensive series

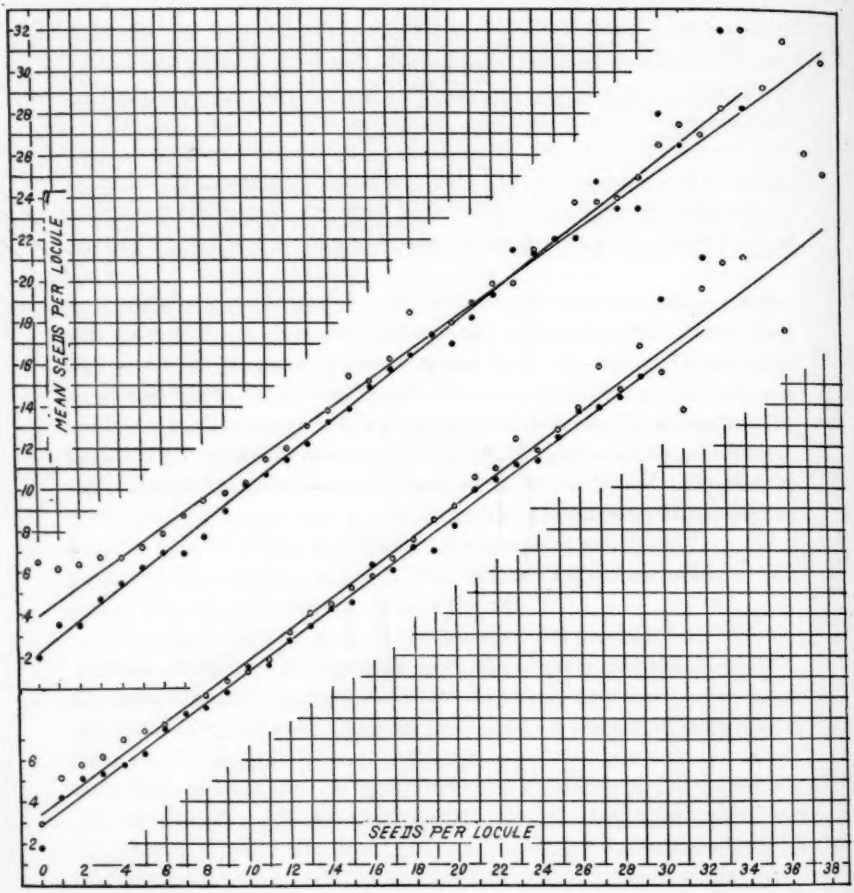

Fig. 13. Regression of number of seeds in the locule of the fruit on number of seeds in another locule of the same fruit. Circles = Meramec Highlands, solid dots = Jefferson Barracks. In both figures the upper lines (at the beginning) represent the equations for the Meramec Highlands series. Lower figure represent series for 1907, upper figure represents series for 1906.

of countings made at Meramec Highlands and Jefferson Barracks, near St. Louis, Mo., in 1906 and 1907. Briefly stated, the results are as follows:

1. The average number and the variation in number of flowers and fruits per inflorescence and seeds per locule in the two habitats and years has been determined, and compared with the available data for fertility in other species. For details reference must be made to the body of the paper.

2. About 22 per cent of the flowers develop their ovaries into fruits. The correlation between the number of flowers formed and the number of fruits matured is of about medium value. This is, however, due to the fact that as the result of chance only the larger inflorescences should produce larger numbers of fruits. A special formula shows that there is little relationship between the size of the inflorescence as measured by the number of flowers which it produces and its capacity for maturing its ovaries into fruits.

3. While the more proximal and more distal flowers on the inflorescence show a smaller proportion of fruit production, there is little relationship between the size of the inflorescence as measured by the number of flowers produced and the position of the flowers which mature their ovaries into fruits.

4. There is practically speaking no correlation between the number of flowers on the inflorescence and the number of seeds matured per locule. This is apparently in part due to the negative correlation between the number of fruits matured and number of seeds per locule. If correction for the number of fruits be made it is shown that the inflorescences which produce the larger numbers of flowers also mature slightly larger numbers of seeds per locule.

5. There is a slight negative correlation between the number of fruits ripened per inflorescence and the number of seeds matured per locule.

The physiological significance of (4) and (5) is considered.

6. The fertility of the fruits tends to decrease slightly, and approximately uniformly, from the proximal to the distal end of the inflorescence.

7. While there is little relationship between number of flowers or number of fruits per inflorescence or position on the inflorescence and the number of seeds per locule, the correlation between the number of seeds in the 3 locules of the fruit is high. Thus

there are as yet unmeasurable factors which influence in a similar manner the seed production of the 3 locules of the same ovary. These may be in part ecological, depending upon accidents of fertilization, and in part physiological.

The result of greatest importance derived from this investigation is the generally low correlation between the meristic characters of the inflorescence and fruit and seed production. While variation in seed production is clearly the resultant of underlying causes, these "causes" are not easily located in the variations of the magnitudes of any of the antecedently formed structures. Thus there is little relationship between the number of flowers formed per inflorescence and the number of seeds matured per locule. This conclusion, that there is but a low correlation between somatic characters and fertility, is in full agreement with those drawn from a consideration of the relationship between the number of parts of the involucral whorl and fertility in *Hibiscus* (Harris, '11).

This conclusion is not shaken by the more substantial correlations formed between number of pods and number of ovules and seeds in *Phaseolus* (Harris, '14), for here, as in *Sanguinaria* (Harris, '10) and in *Nothoscordum* and *Allium* (Harris, '09 b), we have questions of possible age differentiation in the perennials or of the somatic character measured standing more directly in relation to the fertility characters as means of support, conducting tracts for plastic materials, or as an actual source of the elaboration of plastic materials.

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